

EPA REGION 3: PLANTS 3 AND 4

Plant Operations and Sampling

On November 13, 2000, February 5, 2001, August 1, 2001, October 16, 2001, and January 28, 2002, plants 3 and 4 (EPA Region 3) were sampled. Plants 3 and 4 operated in parallel on a common source water (Figures 1-2).

The treatment processes at plant 3 (Figure 3) included flocculation, coagulation, sedimentation, and filtration. The settled water was first filtered through a multimedia filter and then through a granular activated carbon (GAC) filter. The raw water was disinfected with free chlorine. In November 2000, August 2001, and October 2001, ammonia was added to convert the chlorine to chloramines after a 30-sec or 1-min chlorine contact time, whereas ammonia was not added until the plant effluent in February 2001. (Information on the disinfection scheme for January 2002 is not available.) After the GAC and at the plant effluent, additional chlorine was added. In addition, in August and October 2001, chlorine was applied at the end of the sedimentation basin.

The treatment processes at plant 4 (Figures 1-2) included flocculation, coagulation, sedimentation, and filtration. The settled water was filtered through a GAC filter. Chlorine was applied to the raw and filtered waters and at the plant effluent. Chloramines were not used at plant 4.

Plant 3 was sampled at the following locations (Figure 3):

- (1) raw water
- (2) the rapid mix effluent (prior to ammonia addition)
- (3) the GAC influent
- (4) the GAC effluent
- (5) the plant effluent

Plant 4 was sampled at the following locations:

- (1) GAC influent
- (2) GAC effluent
- (3) the plant effluent

In addition, plant effluent samples were collected for both plants, and simulated distribution system (SDS) testing was conducted for average and maximum detention times for that time of year (Table 1). Furthermore, the distribution systems for both plants were sampled at two locations, one representing an average detention time and the other representing a maximum detention time. (Raw water was not sampled at plant 4, as it is the same as is used at plant 3.)

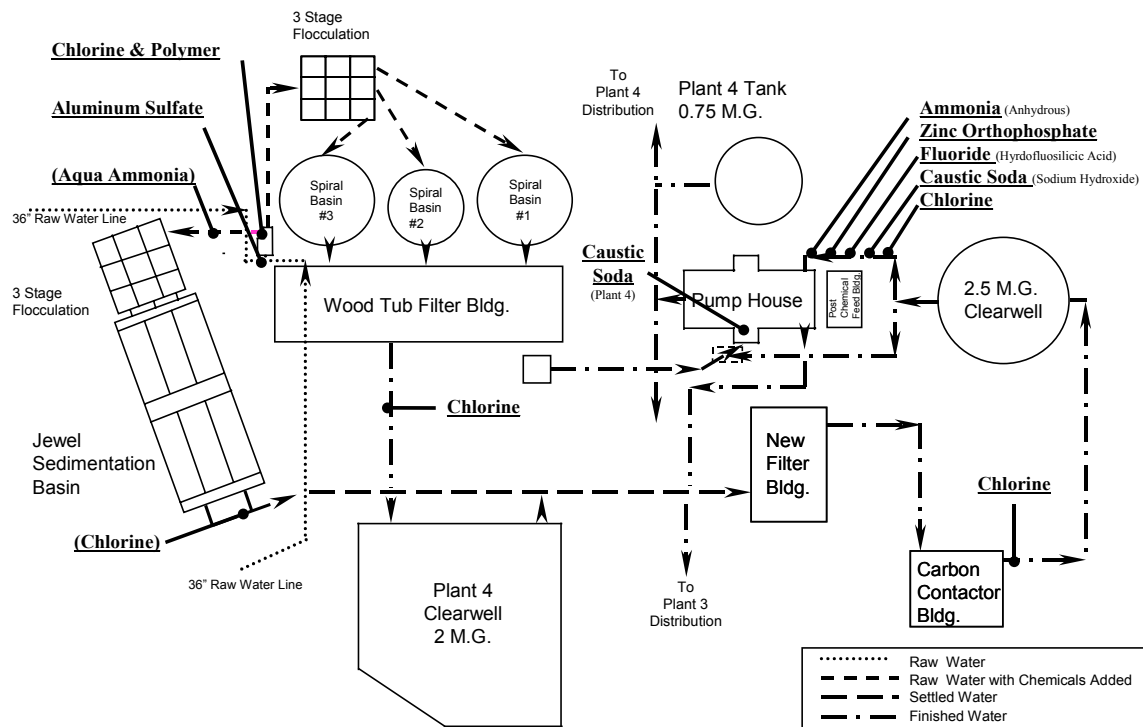


Figure 1. Chemical application points at plants 3 and 4.

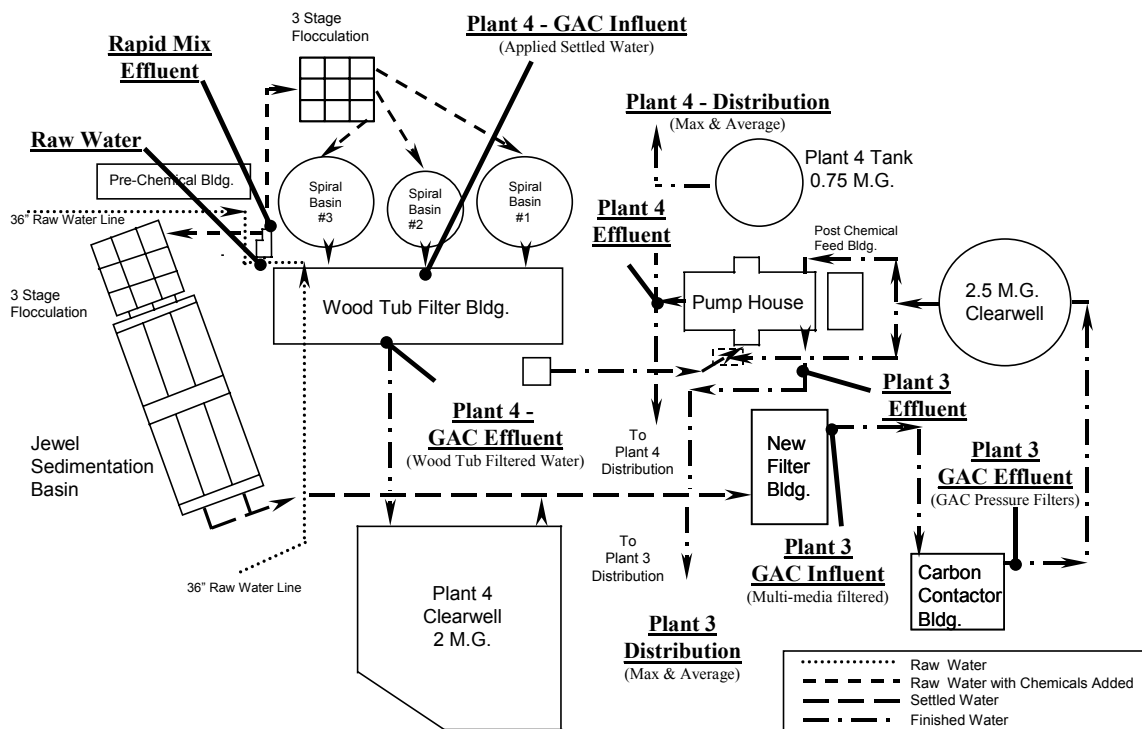


Figure 2. Sampling points at plants 3 and 4.

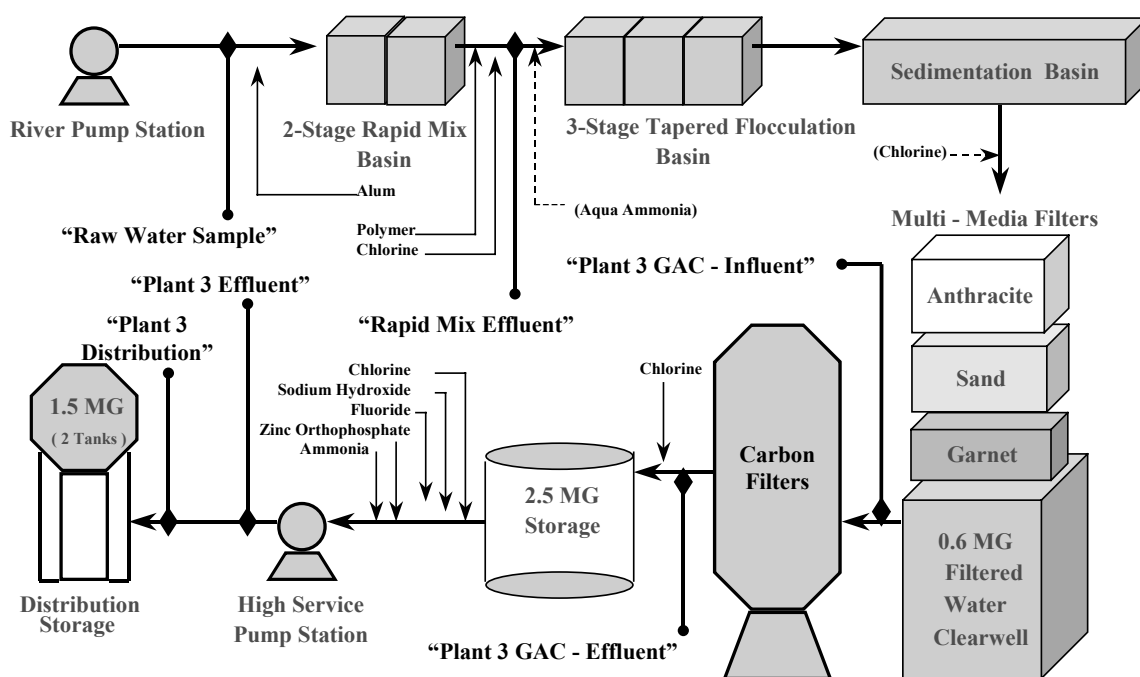


Figure 3. Simplified line diagram of chemical application and sampling points at plant 3.

Table 1. SDS holding times (hr) at plants 3 and 4

Sample	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02
Plant 3 average detention time	20	18	18	77	NA ^a
Plant 3 maximum detention time	28	48	48	140	NA
Plant 4 average detention time	20	20	8	77	NA
Plant 4 maximum detention time	28	30	24	140	NA

^aNA = Not available

On the day of sampling, information was collected on the operations at each plant (Tables 2-3). In February 2001, several of the plant 4 filters had been removed from service. In order to maintain filtered water quality on the plant 4 side, plant 3 carbon contactor filtered (CCF) water was added to the plant 4 suction (clearwell). Thus, 6.0 million gallons per day (mgd) of plant 3 CCF water was added to the plant 4 side. This resulted in 35 % of the plant 4 water being plant 3 CCF water. This affected the results of the plant 4 distribution-system and SDS samples. Likewise, in August and October 2001, blending occurred at the entrance to the plant 4 distribution system, which was a combination of plant 4 and “deep bed GAC” filtered waters (the plant 4 effluent was a combination of water from the plant 3 clearwell and the plant 4 clearwell).

Table 2. Operational information at plant 3

Parameter	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02
Plant flow (mgd)	8	10	9	9	NA
Coagulant ^a dose (mg/L)	60	39	56	91	NA
GAC filter loading rate (gpm/sq ft)	6.14	7.7	6.91	6.91	NA
GAC EBCT ^b (min)	14.9	11.9	13.3	13.3	NA
Chlorine dose at rapid mix (mg/L)	3.3	5.7	6.6	6.6	NA
Ammonia dose at rapid mix eff. (mg/L as N)	0.55	0	0.9	0.9	NA
Chlorine dose at end of sed. basin (mg/L)	0	0	4.0	3.0	NA
Chlorine dose at GAC effluent (mg/L)	1.2	1.2	1.3	1.3	NA
Chlorine dose at plant effluent (mg/L)	2.05	2.5	2.03	2.8	NA
Ammonia dose at plant effluent (mg/L as N)	0.85	0.90	0.82	0.94	NA

^aAluminum sulfate [$\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$]^bEmpty bed contact time**Table 3. Operational information at plant 4**

Parameter	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02
Plant flow (before addition of plant 3 GAC effluent) (mgd)	11.8	11	11	9.9	NA
Flow of plant 3 GAC effluent added to plant 4 (mgd)	0	6.0	4.2	4.9	NA
Coagulant ^a dose (mg/L)	60	39	56	91	NA
GAC filter loading rate (gpm/sq ft)	1.3	1.2	1.13	1.01	NA
GAC EBCT (min)	11.5	12.9	13.3	14.8	NA
Chlorine dose at rapid mix (mg/L)	4.5	5.7	7.6	6.0	NA
Chlorine dose at entrance of plant 4 (filtered water) clearwell (mg/L)	NA	NA	1.35	1.21	NA
Chlorine dose at plant effluent (mg/L)	0.6	0.4	1.2	0.9	NA

^aAluminum sulfate

Water Quality

On the day of sampling, information was collected on the water quality at each plant (Tables 4-5). At plant 3, seasonal control of disinfection by-products (DBPs)—especially trihalomethanes (THMs)—was being achieved using pre-chloramination. During warmer months (e.g., August, October, November), ammonia was added to convert the chlorine to chloramines after a 1-min chlorine contact time, whereas ammonia was not added until the plant effluent during colder months (e.g., February).

Table 4. Water quality information at plant 3

Location	pH					Temperature (°C)					Disinfectant Residual ^a (mg/L)				
	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02
Raw	7.3	6.9	7.3	7.6	NA	13.9	7	25.6	18.9	NA	---	---	---	---	NA
RM ^b eff.	6.1	5.9	6.3	6.0	NA	13.9	7	25.6	18.9	NA	2.2	3.5	3.2	3.2	NA
GAC inf.	6.2	5.5	6.0	6.0	NA	13.9	9	25.6	18.1	NA	0.9	0.5	1.6	1.6	NA
GAC eff.	6.0	5.5	6.1	5.9	NA	13.9	8	24.6	18.9	NA	0.1	0	ND ^c	ND	NA
Plant eff.	7.4	7.2	7.4	7.4	NA	13.9	10	25.6	19.6	NA	3.2	3.5	3.1	3.8	NA
DS ^d /ave.	7.5	7.2	7.4	7.4	NA	13.9	9	26.4	20.2	NA	2.5	2.6	2.8	2.8	NA
DS/max	7.3	7.2	7.4	7.4	NA	13.9	9	26.4	20.2	NA	2.0	2.4	2.4	2.4	NA
SDS/ave.	7.4	7.2	7.4	7.4	NA	13.9	9	24.5	20.2	NA	2.5	2.3	2.8	2.4	NA
SDS/max	7.5	7.2	7.4	7.4	NA	13.9	9	24.5	20.2	NA	2.4	2.0	2.4	2.0	NA

^a11/13/00, 8/1/01, 10/16/01: Chlorine residuals (values shown in italics) at rapid mix effluent; chloramine (or total) residuals at other locations

2/5/01: Chlorine residuals (values shown in italics) at rapid mix effluent, GAC influent and effluent; chloramine residuals at other locations

^bRM = Rapid mix

^cND = Not detected

^dDS = Distribution system

Table 5. Water quality information at plant 4

Location	pH					Temperature (°C)					Chlorine Residual (mg/L)				
	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02
GAC inf.	6.2	5.5	6.1	6.0	NA	13.9	7	25.6	18.9	NA	2.6	1.4	1.5	0.9	NA
GAC eff.	6.2	5.5	6.0	6.0	NA	13.9	7	24.5	18.9	NA	0.6	0.8	0.4	0.4	NA
Plant eff.	7.2	6.8	6.9	7.2	NA	13.9	8	24.5	19.6	NA	1.1	1.2	1.2	1.2	NA
DS/ave.	7.0	6.5	6.9	7.2	NA	13.9	8	25.2	20.2	NA	1.8	1.0	0.8	1.0	NA
DS/max	6.8	6.5	6.9	7.0	NA	13.9	9	25.2	20.2	NA	1.2	0.5	0.9	0.8	NA
SDS/ave.	7.1	6.2	6.9	7.0	NA	13.9	9	24.5	20.2	NA	1.4	0.5	0.8	0.7	NA
SDS/max	7.1	6.2	6.9	7.0	NA	13.9	9	24.5	20.2	NA	1.1	0.5	0.8	0.4	NA

Data were also collected for total organic carbon (TOC) and ultraviolet (UV) absorbance (Table 6). The TOC ranged from 4.3 to 6.4 mg/L, and the UV absorbance from 0.090 to 0.187 cm⁻¹. At plants 3 and 4, coagulation removed 30-59 % of the TOC and GAC filtration removed another 4-23 %. At plant 3, GAC filtration was used to prevent taste-and-odor problems in the finished water and for the removal of other micropollutants, but it was not installed for DBP precursor (TOC) removal. The GAC is only regenerated once every three years at plant 3. At plants 3 and 4, coagulation, GAC filtration, and chlorination cumulatively reduced the UV absorbance by 67-84 %.

Table 6. TOC and UV removal at plants 3 and 4

Location	TOC (mg/L)	UV ^a (cm ⁻¹)	SUVA ^b (L/mg-m)	Removal/Unit (%)		Removal/Cumulative (%)	
				TOC	UV	TOC	UV
11/13/2000							
Raw water	4.37	0.091	2.08	---	---	---	---
Plant 3 GAC inf.	2.34	0.041	1.75	46%	55%	46%	55%
Plant 3 GAC eff.	2.2	0.028	1.27	6.0%	32%	50%	69%
Plant 4 GAC inf.	2.47	0.027	1.09	43%	70%	43%	70%
Plant 4 GAC eff.	2.31	0.029	1.26	6.5%	-7.4%	47%	68%
02/05/2001							
Raw water	6.44	0.187	2.90	---	---	---	---
Plant 3 GAC inf.	2.63	0.038	1.44	59%	80%	59%	80%
Plant 3 GAC eff.	2.46	0.033	1.34	6.5%	13%	62%	82%
Plant 4 GAC inf.	2.70	0.036	1.33	58%	81%	58%	81%
Plant 4 GAC eff.	2.59	0.033	1.27	4.1%	8.3%	60%	82%
08/01/2001							
Raw water	6.25	0.14	2.24	---	---	---	---
Plant 3 GAC inf.	2.63	0.034	1.29	58%	76%	58%	76%
Plant 3 GAC eff.	2.02	0.023	1.14	23%	32%	68%	84%
Plant 4 GAC inf.	3.24	0.03	0.93	48%	79%	48%	79%
Plant 4 GAC eff.	2.69	0.032	1.19	17%	-6.7%	57%	77%
10/16/2001							
Raw water	5.9	0.113	1.92	---	---	---	---
Plant 3 GAC inf.	2.87	0.036	1.25	51%	68%	51%	68%
Plant 3 GAC eff.	2.37	0.028	1.18	17%	22%	60%	75%
Plant 4 GAC inf.	4.13	0.047	1.14	30%	58%	30%	58%
Plant 4 GAC eff.	3.58	0.037	1.03	13%	21%	39%	67%
01/28/2002							
Raw water	4.27	0.090	2.11	---	---	---	---
Plant 3 GAC inf.	2.40	0.030	1.25	44%	67%	44%	67%
Plant 3 GAC eff.	2.23	0.029	1.30	7.1%	3.3%	48%	68%
Plant 4 GAC inf.	2.85	0.031	1.09	33%	66%	33%	66%
Plant 4 GAC eff.	2.45	0.029	1.18	14%	6.5%	43%	68%

^aUV = Ultraviolet absorbance reported in units of "inverse centimeters" (APHA, 1998)

^bSUVA (L/mg-m) = Specific ultraviolet absorbance = 100*UV (cm-1)/DOC (mg/L) or UV (m-1)/DOC (mg/L), where DOC = dissolved organic carbon, which typically = 90-95% TOC (used TOC values in calculating SUVA) (e.g., UV = 0.091/cm = 0.091/(0.01 m) = 9.1/m, DOC = 4.37 mg/L, SUVA = (9.1 m-1)/(4.37 mg/L) = 2.08 L/mg-m)

Table 7 shows other water quality parameters for the raw source water for plants 3 and 4. Note, that source water received a tremendous amount of rainfall the weekend before the August 2001 sampling, which may have diluted some of these water quality parameters.

Table 7. Miscellaneous water quality parameters in plants 3 and 4 raw water

Date	Bromide (mg/L)	Alkalinity (mg/L)	Ammonia (mg/L as N)
11/13/2000	0.058	69	0.07
02/05/2001	0.022	27	0.1
08/01/2001	0.05	49	0.08
10/16/2001	0.2	61	0.09
01/28/2002	0.023	38	0.12

Bromide was lowest in winter (0.02 mg/L) and highest in summer and fall (0.05-0.2 mg/L). The source water for plants 3 and 4 is a river, with intakes located 1.5 miles upstream of the confluence with another river. This area is influenced by the tides and is prone to flow reversal at the intakes. As much as 70 % of the source water can be contributed from the latter river, especially during low-flow conditions. Tidal influences were the source of bromide and should also have been a source of iodide.

The source water was relatively low in alkalinity. The addition of coagulant and chlorine depressed the pH of this low-alkalinity water to 5.5-6.3. Raw-water ammonia ranged from 0.07 to 0.12 mg/L as N.

DBPs

Tables 8-17 show results for the DBPs that were analyzed at the Metropolitan Water District of Southern California (MWDSC) for sampling periods 11/13/00, 2/5/01, 8/1/01, 10/16/01, and 1/28/02. Tables 18 (2/5/01), 19 (10/16/01), and 20 (10/16/01) show results for additional target DBPs that were analyzed at the University of North Carolina (UNC), which include halofuranones. Table 21 shows results from broadscreen DBP analyses conducted at the U.S. Environmental Protection Agency (USEPA) for sampling periods 11/13/00, 8/1/01, and 1/28/02.

Summary of tables for halogenated organic and other nonhalogenated organic DBPs

DBP Analyses (Laboratory)	11/13/00	2/5/01	8/1/01	10/16/01	1/28/02
Halogenated organic DBPs (MWDSC)	Tables 8-9	Tables 10-11	Tables 12-13	Tables 14-15	Tables 16-17
Additional target DBPs (UNC)		Table 18		Table 19	
Halogenated furanones (UNC)				Table 20	
Broadscreen analysis (USEPA)	Table 21		Table 21		Table 21

Table 8. DBP results at plant 3 (11/13/00)

11/13/2000	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	SDS/Ave	SDS/Max	DS/Ave	DS/Max
Halomethanes										
Chloromethane	0.15	ND ^d		ND	ND	ND	ND		ND	
Bromomethane	0.20	ND		ND	ND	ND	ND		ND	
Bromochloromethane	0.14	ND		ND	ND	ND	ND		ND	
Dibromomethane	0.11	ND		ND	ND	ND	ND		ND	
Chloroform ^e	0.10	0.7	5	7	9	12	16	20	14	18
Bromodichloromethane ^e	0.10	0.7	4	9	9	13	17	19	15	19
Dibromochloromethane ^e	0.12	0.3	1	3	2	5	7	8	6	7
Bromoform ^e	0.10	ND	0.7	0.8	0.4	0.7	1	1	0.8	1
THM4 ^f		2	11	20	20	31	41	48	36	45
Dichloroiodomethane	0.10	ND	NR ^g	2	1	2	2	NR	2	NR
Bromochloroiodomethane	0.50	ND	NR	NR	NR	NR	NR	NR	NR	NR
Dibromoiodomethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.59	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.53	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.22	ND	0.7	ND	ND	0.5	0.6	0.9	0.9	0.4
Carbon tetrachloride	0.06	ND		0.8	0.3	0.3	0.3		0.3	
Haloacetic acids										
Monochloroacetic acid ^e	2			ND	3.2	ND	4.2		3.9	
Monobromoacetic acid ^e	1			ND	ND	ND	ND		ND	
Dichloroacetic acid ^e	1			12	ND	6.7	6.9		6.4	
Bromochloroacetic acid ^e	1			7.1	ND	3.0	3.1		3.0	
Dibromoacetic acid ^e	1			1.2	ND	1.0	1.0		ND	
Trichloroacetic acid ^e	1			10	ND	6.0	5.6		5.6	
Bromodichloroacetic acid	1			3.3	ND	2.6	2.5		2.4	
Dibromochloroacetic acid	1			1.2	ND	1.1	1.0		1.1	
Tribromoacetic acid	2			ND	ND	ND	ND		ND	
HAA5 ^h				24	3.2	14	18		16	
HAA9 ⁱ				36	3.2	20	24		22	
DXAA ^j				21	ND	11	11		9.4	
TXAA ^k				15	ND	9.7	9.1		9.1	
Haloacetonitriles										
Chloroacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	ND	0.5	0.9	0.2	1	2	2	1	2
Bromochloroacetonitrile ^e	0.10	ND	0.2	0.3	ND	0.9	1	1	0.8	1
Dibromoacetonitrile ^e	0.10	ND	ND	ND	ND	0.3	0.2	0.3	0.2	0.2
Trichloroacetonitrile ^e	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloketones										
Chloropropanone	0.10	ND	0.2	0.3	ND	ND	0.3	0.3	0.1	0.2
1,1-Dichloropropanone ^e	0.10	ND	0.5	1	0.1	0.5	0.6	0.6	0.3	0.5
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3	ND		ND	ND	ND	ND		ND	
1,1,1-Trichloropropanone ^e	0.10	ND	1	1	0.3	0.9	1	1	1	1
1,1,3-Trichloropropanone	0.10	ND	0.2	0.2	ND	ND	0.1	ND	ND	ND
1-Bromo-1,1-dichloropropanone	3	ND		<3 ^l	ND	<3	ND		<3	
1,1,1-Tribromopropanone	3	ND		ND	ND	ND	ND		ND	
1,1,3-Tribromopropanone	3	ND		ND	ND	ND	ND		ND	
1,1,3,3-Tetrachloropropanone	0.10	ND	0.2	0.2	ND	0.2	0.1	0.1	0.1	0.1
1,1,3,3-Tetrabromopropanone	0.10	ND	0.1	ND	ND	ND	ND	ND	ND	ND

Table 8 (continued)

11/13/2000	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	SDS/Ave	SDS/Max	DS/Ave	DS/Max
<u>Haloacetaldehydes</u>										
Dichloroacetaldehyde	0.16	0.1	0.8	2	0.2	0.8	1	1	0.6	2
Bromochloroacetaldehyde ^m										
Chloral hydrate ^{e,m}	0.20	ND	0.8	4	ND	2	4	4	2	4
Tribromoacetaldehyde	0.10	ND	0.2	0.2	ND	ND	0.1	0.2	ND	ND
<u>Halonitromethanes</u>										
Bromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3	ND		ND	ND	ND	ND		ND	
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.10	ND	ND	0.1	ND	ND	ND	0.1	ND	0.2
<u>Miscellaneous Compounds</u>										
Methyl ethyl ketone	1.90	ND		ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16	1.0		1.0	1.0	1.1	1.0		1.1	
Benzyl chloride	0.50	NR	NR	NR	NR	NR	NR	NR	NR	NR

^aMRL = Minimum reporting level, which equals method detection limit (MDL) or lowest calibration standard or concentration of blank

^bPlant 3 sampled at (1) raw water, (2) effluent of rapid mix, (3) GAC influent and (4) effluent, (5) plant effluent, (6) SDS testing of plant effluent held for average detention time and (7) held for maximum detention time, (8) DS at average detention time and (9) at maximum detention time.

^cPlant 4 sampled at (1) GAC influent and (2) effluent, (3) plant effluent, (4) SDS testing of plant effluent held for average detention time and (5) held for maximum detention time, (6) DS at average detention time and (7) at maximum detention time.

^dND = Not detected at or above MRL

^eDBP in the Information Collection Rule (ICR) (note: some utilities collected data for all 9 haloacetic acids for the ICR, but monitoring for only 6 haloacetic acids was required)

^fTHM4 = Sum of 4 THMs (chloroform, bromodichloromethane, dibromochloromethane, bromoform)

^gNR = Not reported, due to interference problem on gas chromatograph or to problem with quality assurance

^hHAA5 = Sum of 5 haloacetic acids (monochloro-, monobromo-, dichloro-, dibromo-, trichloroacetic acid)

ⁱHAA9 = Sum of 9 haloacetic acids

^jDXAA = Sum of dihaloacetic acids (dichloro-, bromochloro-, dibromoacetic acid)

^kTXAA = Sum of trihaloacetic acids (trichloro-, bromodichloro-, dibromochloro-, tribromoacetic acid)

^l<3: Concentration less than MRL of 3 µg/L

^mBromochloroacetaldehyde and chloral hydrate co-elute; result = sum of 2 DBPs

Table 9. DBP results at plant 4 (11/13/00)

11/13/2000	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	SDS/Ave	SDS/Max	DS/Ave	DS/Max
<u>Halomethanes</u>								
Chloromethane	0.15	ND	ND	ND	ND		ND	
Bromomethane	0.20	ND	ND	ND	ND		ND	
Bromochloromethane	0.14	ND	ND	ND	ND		ND	
Dibromomethane	0.11	ND	ND	ND	ND		ND	
Chloroform ^e	0.10	30	33	43	56	61	41	46
Bromodichloromethane ^e	0.10	17	21	28	33	37	24	27
Dibromochloromethane ^e	0.12	5	6	7	7	8	6	7
Bromoform ^e	0.10	1	1	1	0.9	0.9	1	0.9
THM4 ^f		53	61	79	97	107	72	81
Dichloriodomethane	0.10	1	1	1	1	NR	1	NR
Bromochloriodomethane	0.50	NR	NR	NR	NR	NR	NR	NR
Dibromiodomethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.59	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.53	ND	0.6	ND	ND	ND	ND	ND
Iodoform	0.22	0.5	0.3	2	2	2	2	2
Carbon tetrachloride	0.06	0.3	0.4	0.8	0.7		0.7	
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2	7.7	12	6.4	11		5.1	
Monobromoacetic acid ^e	1	1.0	ND	ND	1.5		ND	
Dichloroacetic acid ^e	1	24	23	27	30		22	
Bromochloroacetic acid ^e	1	7.0	6.4	8.0	9.4		5.9	
Dibromoacetic acid ^e	1	1.0	ND	1.0	1.2		ND	
Trichloroacetic acid ^e	1	27	27	32	34		24	
Bromodichloroacetic acid	1	11	11	13	14		9.7	
Dibromochloroacetic acid	1	1.7	1.7	2.0	2.3		1.6	
Tribromoacetic acid	2	ND	ND	ND	ND		ND	
HAA5 ^h		61	61	66	78		52	
HAA9 ⁱ		81	81	89	103		69	
DXAA ^j		32	29	36	41		28	
TXAA ^k		40	40	46	50		36	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.10	ND	ND	0.1	0.1	0.1	ND	0.1
Bromoacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	5	5	5	5	6	5	5
Bromochloroacetonitrile ^e	0.10	1	1	1	2	2	1	1
Dibromoacetonitrile ^e	0.10	0.1	0.1	0.2	0.2	0.2	0.1	0.1
Trichloroacetonitrile ^e	0.10	0.2	0.2	0.1	ND	ND	0.1	0.1
<u>Haloketones</u>								
Chloropropanone	0.10	0.4	0.5	0.3	0.2	0.2	0.2	0.3
1,1-Dichloropropanone ^e	0.10	1	1	0.9	0.3	0.3	1	0.8
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3	ND	ND	ND	ND		ND	
1,1,1-Trichloropropanone ^e	0.10	5	5	5	6	7	5	5
1,1,3-Trichloropropanone	0.10	0.3	0.3	0.2	0.2	0.2	0.4	0.3
1-Bromo-1,1-dichloropropanone	3	<3	<3	<3	<3		<3	
1,1,1-Tribromopropanone	3	ND	ND	ND	ND		ND	
1,1,3-Tribromopropanone	3	ND	ND	ND	ND		ND	
1,1,3,3-Tetrachloropropanone	0.10	0.6	0.8	0.4	0.4	0.4	0.7	0.4
1,1,3,3-Tetrabromopropanone	0.10	0.3	0.2	0.1	0.3	0.3	0.2	0.2

Table 9 (continued)

11/13/2000	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	SDS/Ave	SDS/Max	DS/Ave	DS/Max
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.16	4	5	3	2	3	3	3
Bromochloroacetaldehyde ^m								
Chloral hydrate ^{e,m}	0.20	12	13	14	18	22	15	15
Tribromoacetaldehyde	0.10	0.1	0.1	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3	ND	ND	ND	ND		ND	
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.10	0.2	0.2	0.2	0.2	0.3	0.2	0.2
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	1.90	ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16	0.8	0.8	0.8	0.9		0.9	
Benzyl chloride	0.50	NR	NR	NR	NR	NR	NR	NR

Table 10. DBP results at plant 3 (2/5/01)

02/05/2001	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.15	ND ^d		ND	ND	ND	ND		ND	
Bromomethane	0.20	ND		ND	ND	ND	ND		ND	
Bromochloromethane	0.14	ND		ND	ND	ND	ND		ND	
Dibromomethane	0.11	ND		ND	ND	ND	ND		ND	
Chloroform ^e	0.1	0.5	5.5	15	21	27	33	37	33	40
Bromodichloromethane ^e	0.1	ND	1.0	3.1	3.7	5.3	5.9	6.0	5.8	6.4
Dibromochloromethane ^e	0.10	ND	ND	0.4	0.6	0.8	0.8	0.9	0.9	0.9
Bromoform ^e	0.12	ND	ND	ND	0.1	0.1	0.3	0.3	0.3	0.3
THM4 ^f		0.5	6.5	18	25	33	40	44	40	48
Dichloroiodomethane	0.25	ND	NR ^g	0.29	0.27	0.30	0.31	NR	0.26	NR
Bromochloroiodomethane	0.20	ND	NR	ND	ND	ND	ND	NR	ND	NR
Dibromoiodomethane	0.60	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.51	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.56	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.54	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND		ND	ND	ND	ND		ND	
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid ^e	2			3.6	ND	2.3	2.8		2.6	
Monobromoacetic acid ^e	1			ND	ND	ND	ND		ND	
Dichloroacetic acid ^e	1			25	4.2	11	12		11	
Bromochloroacetic acid ^e	1			1.7	ND	1.2	1.2		1.2	
Dibromoacetic acid ^e	1			ND	ND	ND	ND		ND	
Trichloroacetic acid ^e	1			28	15	19	21		19	
Bromodichloroacetic acid	1			2.4	1.3	1.9	1.9		1.8	
Dibromochloroacetic acid	1			ND	ND	ND	ND		ND	
Tribromoacetic acid	2			ND	ND	ND	ND		ND	
HAA5 ^h				57	19	32	36		33	
HAA9 ⁱ				61	21	35	39		36	
DXAA ^j				27	4.2	12	13		12	
TXAA ^k				30	16	21	23		21	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	ND	0.6	2.4	1.6	2.2	2.4	2.4	2.4	2.5
Bromochloroacetonitrile ^e	0.1	ND	ND	0.2	ND	0.2	0.2	0.2	0.2	0.3
Dibromoacetonitrile ^e	0.17	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloketones										
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone ^e	0.11	ND	1.1	0.9	0.5	0.6	1.0	1.1	1.1	1.2
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	N/A ⁿ	NR		NR	NR	NR	NR		NR	
1,3-Dibromopropanone	N/A	NR		NR	NR	NR	NR		NR	
1,1,1-Trichloropropanone ^e	0.10	ND	1.6	3.1	2.4	2.5	2.7	2.6	2.4	2.4
1,1,3-Trichloropropanone	0.10	ND	0.3	0.2	0.2	0.2	0.2	0.2	ND	0.2
1-Bromo-1,1-dichloropropanone	N/A	NR		NR	NR	NR	NR		NR	
1,1,1-Tribromopropanone	N/A	NR		NR	NR	NR	NR		NR	
1,1,3-Tribromopropanone	N/A	NR		NR	NR	NR	NR		NR	
1,1,3,3-Tetrachloropropanone	0.12	ND	0.4	0.7	0.5	0.4	0.6	0.4	0.2	0.4
1,1,1,3-Tetrachloropropanone	N/A	NR		NR	NR	NR	NR		NR	
1,1,3,3-Tetrabromopropanone	0.58	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 10 (continued)

02/05/2001	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloacetaldehydes</u>										
Dichloroacetaldehyde	0.16	ND	0.8	2	1	1	1	1	2	2
Bromochloroacetaldehyde	0.1	ND	ND	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chloral hydrate ^c	0.1	ND	1.0	3.0	1.8	2.7	3.8	3.6	3.4	3.6
Tribromoacetaldehyde	0.1	ND	0.2	0.2	0.1	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>										
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	N/A	NR		NR	NR	NR	NR		NR	
Bromochloronitromethane	N/A	NR		NR	NR	NR	NR		NR	
Dibromonitromethane	0.12	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^c	0.1	ND	0.4	0.8	0.2	0.3	0.4	0.5	0.5	0.6
<u>Miscellaneous Compounds</u>										
Methyl ethyl ketone	1.9	ND		ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16	0.4		0.5	0.5	0.4	0.5		0.4	
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND	ND	ND

^aN/A = Not applicable

Table 11. DBP results at plant 4 (2/5/01)

02/05/2001	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>								
Chloromethane	0.15	ND	ND	ND	ND		ND	
Bromomethane	0.20	ND	ND	ND	ND		ND	
Bromochloromethane	0.14	ND	ND	ND	ND		ND	
Dibromomethane	0.11	ND	ND	ND	ND		ND	
Chloroform ^e	0.1	24	27	29	33	33	36	42
Bromodichloromethane ^e	0.1	3.3	3.8	4.3	4.7	4.7	5.3	6.1
Dibromochloromethane ^e	0.10	0.5	0.5	0.7	0.7	0.7	0.8	0.9
Bromoform ^e	0.12	0.1	ND	0.1	0.1	0.3	0.1	ND
THM4 ^f		28	31	34	39	38	42	49
Dichloriodomethane	0.25	0.27	0.25	0.29	0.28	NR	0.29	NR
Bromochloriodomethane	0.20	ND	ND	ND	ND	NR	ND	NR
Dibromiodomethane	0.60	ND	ND	ND	ND	ND	ND	ND
Chlorodiodomethane	0.51	ND	ND	ND	ND	ND	ND	ND
Bromodiodomethane	0.56	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.54	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND	ND	ND	ND		ND	
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2	5.1	5.5	4.7	5.7		6.3	
Monobromoacetic acid ^e	1	ND	ND	ND	ND		ND	
Dichloroacetic acid ^e	1	32	31	25	25		28	
Bromochloroacetic acid ^e	1	1.9	1.9	1.7	1.7		1.9	
Dibromoacetic acid ^e	1	ND	ND	ND	ND		ND	
Trichloroacetic acid ^e	1	33	35	35	35		38	
Bromodichloroacetic acid	1	3.5	3.6	3.3	3.6		4.6	
Dibromochloroacetic acid	1	1.0	1.0	ND	ND		ND	
Tribromoacetic acid	2	ND	ND	ND	ND		ND	
HAA5 ^h		70	72	65	66		72	
HAA9 ⁱ		77	78	70	71		79	
DXAA ^j		34	33	27	27		30	
TXAA ^k		38	40	38	39		43	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	2.6	2.8	2.7	2.8	2.8	3.2	3.4
Bromochloroacetonitrile ^e	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4
Dibromoacetonitrile ^e	0.17	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile ^e	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<u>Haloketones</u>								
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone ^e	0.11	1.0	1.0	0.9	1.0	1.0	1.0	1.0
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	N/A	NR	NR	NR	NR		NR	
1,3-Dibromopropanone	N/A	NR	NR	NR	NR		NR	
1,1,1-Trichloropropanone ^e	0.10	3.2	3.3	3.1	3.2	3.3	3.7	4.0
1,1,3-Trichloropropanone	0.10	0.3	0.3	0.2	0.3	0.2	0.3	0.2
1-Bromo-1,1-dichloropropanone	N/A	NR	NR	NR	NR		NR	
1,1,1-Tribromopropanone	N/A	NR	NR	NR	NR		NR	
1,1,3-Tribromopropanone	N/A	NR	NR	NR	NR		NR	
1,1,3,3-Tetrachloropropanone	0.12	0.5	0.6	0.6	0.5	0.5	0.6	0.5
1,1,1,3-Tetrachloropropanone	N/A	NR	NR	NR	NR		NR	
1,1,3,3-Tetrabromopropanone	0.58	ND	ND	ND	ND	ND	ND	ND

Table 11 (continued)

02/05/2001	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloacetaldehydes								
Dichloroacetaldehyde	0.16	2	3	2	2	2	2	2
Bromochloroacetaldehyde	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chloral hydrate ^e	0.1	3.2	3.6	4.5	4.4	4.7	6.9	7.5
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes								
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	N/A	NR	NR	NR	NR		NR	
Bromochloronitromethane	N/A	NR	NR	NR	NR		NR	
Dibromonitromethane	0.12	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	0.8	0.8	0.6	0.6	0.6	0.7	0.7
Miscellaneous Compounds								
Methyl ethyl ketone	1.9	ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16	0.5	0.4	0.5	0.5		0.5	
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND

Table 12. DBP results at plant 3 (8/1/01)

08/01/2001	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2	ND ^d		0.3	ND	ND	ND		ND	
Bromomethane	0.2	ND		ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND		ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND		ND	ND	ND	ND		ND	
Chloroform ^e	0.1	0.2	3	8	14	16	19	18	19	NR ^g
Bromodichloromethane ^e	0.1	0.1	0.9	4	5	7	8	7	8	NR
Dibromochloromethane ^e	0.1	ND	0.2	0.8	0.6	2	2	2	2	NR
Bromoform ^e	0.11	ND	ND	ND	ND	0.3	0.3	0.2	0.4	0.5
THM4 ^f		0.3	4.1	13	20	25	28	27	29	NR
Dichloriodomethane	0.5	ND	NR	<0.5 ^o	ND	ND	ND	ND	ND	NR
Bromochloriodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND		ND	ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid ^e	2			3.9	ND	2.2	ND		2.3	
Monobromoacetic acid ^e	1			1.2	ND	ND	ND		ND	
Dichloroacetic acid ^e	1			25	ND	6.4	8.7		7.3	
Bromochloroacetic acid ^e	1			6.5	1.6	2.7	3.2		3.1	
Dibromoacetic acid ^e	1			1.1	ND	1.0	1.0		ND	
Trichloroacetic acid ^e	1			16	ND	2.2	2.3		2.2	
Bromodichloroacetic acid	1			4.6	ND	1.5	1.4		1.4	
Dibromochloroacetic acid	1			1.2	ND	ND	ND		ND	
Tribromoacetic acid	2			ND	ND	ND	ND		ND	
HAA5 ^h				47	ND	12	12		12	
HAA9 ⁱ				60	2	16	17		16	
DXAA ^j				33	2	10	13		10	
TXAA ^k				22	ND	3.7	3.7		3.6	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	ND	0.6	4	0.1	0.9	1	1	2	2
Bromochloroacetonitrile ^e	0.1	ND	0.1	0.8	ND	0.7	0.8	0.8	0.9	1
Dibromoacetonitrile ^e	0.14	ND	ND	0.2	ND	0.6	0.7	0.5	0.8	0.8
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND		ND	ND	ND				
Dibromochloroacetonitrile	0.5	ND		ND	ND	ND				
Tribromoacetonitrile	0.5	ND		ND	ND	ND				
Haloketones										
Chloropropanone	0.1	ND	ND	0.1	0.1	0.1	0.1	0.1	0.3	0.3
1,1-Dichloropropanone ^e	0.10	ND	0.9	2	0.2	0.4	1	1	0.8	1
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.1	ND	1	2	0.2	0.8	0.5	0.2	0.8	0.4
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	0.5	ND	0.2	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.29	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	2 ^p	1 ^p	0.6 ^p	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	0.1	0.2	0.3	ND	ND	ND	ND

Table 12 (continued)

08/01/2001	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloacetaldehydes</u>										
Dichloroacetaldehyde	0.1	ND	0.8	4	0.9	1	3	3	2	4
Bromochloroacetaldehyde	0.1	ND	ND	2	ND	ND	0.5	ND	0.4	0.5
Chloral hydrate ^e	0.1	ND	ND	3 ^p	0.6 ^p	2 ^p	2 ^p	2 ^p	2 ^p	2 ^p
Tribromoacetaldehyde	0.1	ND	ND	1 ^p	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>										
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloronitromethane	0.5	ND		ND	ND	ND				
Dibromochloronitromethane	0.5	ND		ND	ND	ND				
Bromopicrin	2.0	ND		ND	ND	ND				
<u>Miscellaneous Compounds</u>										
Methyl ethyl ketone	0.5	28		12	15	5	5		2	
Methyl <i>tertiary</i> butyl ether	0.2	1		1	1	1	1		0.9	
1,1,2,2-Tetrabromo-2-chloroethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.25	ND	NR	ND	ND	ND	ND	NR	ND	NR

^e<0.5: Detected by SPE-GC/MS, but below MRL for SPE-GC/MS

^pLow spike recoveries for 1,1,1,3- and 1,1,3,3-tetrachloropropanone and for chloral hydrate and tribromoacetaldehyde.

Table 13. DBP results at plant 4 (8/1/01)

08/01/2001	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>								
Chloromethane	0.2	ND	ND	ND	ND		ND	
Bromomethane	0.2	ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND	ND		ND	
Chloroform ^e	0.1	22	27	22	27	27	27	25
Bromodichloromethane ^e	0.1	7	9	8	9	10	9	9
Dibromochloromethane ^e	0.1	1	1	1	1	2	2	2
Bromoform ^e	0.11	ND	ND	ND	ND	ND	ND	0.1
THM4 ^f		30	37	31	38	39	38	36
Dichloriodomethane	0.5	ND	ND	ND	ND	NR	0.5	NR
Bromochloriodomethane	0.5	ND	ND	ND	ND	ND	ND	ND
Dibromiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND	ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2	20	16	8.2	7.8		8.1	
Monobromoacetic acid ^e	1	ND	ND	ND	ND		ND	
Dichloroacetic acid ^e	1	56	25	24	25		26	
Bromochloroacetic acid ^e	1	8.7	4.5	4.5	4.9		5.1	
Dibromoacetic acid ^e	1	ND	ND	ND	ND		ND	
Trichloroacetic acid ^e	1	68	49	29	31		30	
Bromodichloroacetic acid	1	12	8.7	6.8	7.3		7.0	
Dibromochloroacetic acid	1	1.9	1.3	1.3	1.2		1.2	
Tribromoacetic acid	2	ND	ND	ND	ND		ND	
HAA5 ^h		144	90	61	64		64	
HAA9 ⁱ		167	105	74	77		77	
DXAA ^j		65	30	29	30		31	
TXAA ^k		82	59	37	40		38	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	10	10	6	8	8	8	8
Bromochloroacetonitrile ^e	0.1	1	1	1	1	1	1	1
Dibromoacetonitrile ^e	0.14	0.8	0.3	0.4	0.4	0.5	0.4	0.4
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND	ND	ND				ND
Dibromochloroacetonitrile	0.5	ND	ND	ND				ND
Tribromoacetonitrile	0.5	ND	ND	ND				ND
<u>Haloketones</u>								
Chloropropanone	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2
1,1-Dichloropropanone ^e	0.10	3	2	0.9	1	0.8	0.8	1
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.1	8	7	4	6	6	6	5
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	0.7	0.7	0.4	0.5	0.4	0.3	0.1
1,1,1-Tribromopropanone	0.29	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	2 ^p	1 ^p	0.7 ^p	1 ^p	ND	0.7 ^p	0.2 ^p
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND

Table 13 (continued)

08/01/2001	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.1	8	4	3	3	3	5	5
Bromochloroacetaldehyde	0.1	2	0.4	0.4	0.3	0.3	0.3	0.4
Chloral hydrate ^e	0.1	16 ^p	6 ^p	6 ^p	4 ^p	4 ^p	7 ^p	11 ^p
Tribromoacetaldehyde	0.1	2 ^p	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	ND	ND	ND	0.2	0.2
Bromodichloronitromethane	0.5	ND	ND	ND				ND
Dibromochloronitromethane	0.5	ND	ND	ND				ND
Bromopicrin	2.0	ND	ND	ND				ND
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5	24	23	ND	0.5		0.6	
Methyl <i>tertiary</i> butyl ether	0.2	2	2	1	1		0.9	
1,1,2,2-Tetrabromo-2-chloroethane	0.1	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.25	ND	ND	ND	ND	NR	ND	NR

^eDBP in the Information Collection Rule (ICR) (note: some utilities collected data for all 9

haloacetic acids for the ICR, but monitoring for only 6 haloacetic acids was required)

^pLow spike recoveries for 1,1,1,3- and 1,1,3,3-tetrachloropropanone and for chloral hydrate and tribromoacetaldehyde.

Table 14. DBP results at plant 3 (10/16/01)

10/16/2001	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2	ND ^d		ND	ND	ND	ND		ND	
Bromomethane	0.2	ND		ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND		ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND		ND	ND	ND	ND		ND	
Chloroform ^e	0.1	ND	1	8	12	18	19	20	16	23
Bromodichloromethane ^e	0.1	0.2	2	13	14	24	26	27	24	36
Dibromochloromethane ^e	0.1	ND	0.8	7	6	11	12	14	10	22
Bromoform ^e	0.25	ND	0.2	2	0.8	2	3	2	4	3
THM4 ^f		0.2	4	30	33	55	60	63	54	84
Dichloriodomethane	0.5	ND	NR ^g	ND	ND	ND	0.8	NR	0.5	NR
Bromochloriodomethane	0.5	ND	NR	ND	ND	ND	ND	NR	ND	NR
Dibromiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.1	ND	ND	ND	ND	ND	ND	ND	NR	NR
Carbon tetrachloride	0.2	ND		ND	ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid ^e	2			ND	ND	ND	ND		ND	
Monobromoacetic acid ^e	1			ND	ND	ND	ND		ND	
Dichloroacetic acid ^e	1			14	ND	4.6	4.7		3.4	
Bromochloroacetic acid ^e	1			7.8	ND	3.4	3.6		4.2	
Dibromoacetic acid ^e	1			3.5	ND	2.6	2.6		3.0	
Trichloroacetic acid ^e	1			9.8	ND	1.2	1.4		1.4	
Bromodichloroacetic acid	1			8.2	ND	3.3	3.4		2.4	
Dibromochloroacetic acid	1			3.2	ND	2.0	2.1		1.7	
Tribromoacetic acid	2			ND	ND	ND	ND		ND	
HAA5 ^h				27	ND	8.4	8.7		7.8	
HAA9 ⁱ				47	ND	17	18		16	
DXAA ^j				25	ND	11	11		11	
TXAA ^k				21	ND	6.5	6.9		5.5	
Haloacetonitriles										
Chloroacetonitrile	0.2	ND	NR	0.5	ND	0.3	0.4	NR	0.4	NR
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.1	ND	0.5	2	0.2	0.7	0.8	0.9	1	2
Bromochloroacetonitrile ^e	0.1	ND	0.4	2	ND	1	2	2	2	2
Dibromoacetonitrile ^e	0.1	ND	0.5	2	0.1	0.7	0.7	0.8	1	1
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND		ND	ND	ND				
Dibromochloroacetonitrile	0.5	ND		ND	ND	ND				
Tribromoacetonitrile	0.90	ND		ND	ND	ND				
Haloketones										
Chloropropanone	0.1	ND	0.3	0.5	0.4	0.6	0.5	0.6	0.4	0.5
1,1-Dichloropropanone ^e	0.10	ND	0.7	1	0.2	0.4	0.4	0.4	0.3	0.4
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	0.4	ND	0.1	ND	0.1	ND	ND
1,1,1-Trichloropropanone ^e	0.1	ND	0.6	1	0.2	0.5	0.5	0.5	0.2	0.2
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	0.5	1	ND	0.4	0.2	0.1	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	0.5	2	ND	0.4	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	0.4	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 14 (continued)

10/16/2001	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloacetaldehydes										
Dichloroacetaldehyde	0.22	ND	0.9	4	0.2	0.7	1	1	1	2
Bromochloroacetaldehyde	0.5	ND	ND	2	ND	ND	1	1	1	2
Chloral hydrate ^e	0.1	ND	0.3	4	0.3	0.7	1	2	0.7	1
Tribromoacetaldehyde	0.1	ND	ND	1	ND	ND	0.1	ND	ND	ND
Halonitromethanes										
Chloronitromethane	0.1	ND	0.2	0.3	ND	ND	ND	0.1	NR	NR
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	0.2	0.2
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	0.1	ND	ND	ND	ND	ND	0.2
Bromodichloronitromethane	0.5	ND		0.5	ND	ND				
Dibromochloronitromethane	0.5	ND		0.6	ND	0.5				
Bromopicrin	0.5	ND		ND	ND	ND				
Miscellaneous Compounds										
Methyl ethyl ketone	0.5	0.6		3	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2	1		1	1	1	1		0.9	
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.25	ND	NR	ND	ND	ND	ND	NR	ND	NR

Table 15. DBP results at plant 4 (10/16/01)

10/16/2001	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>								
Chloromethane	0.2	ND	ND	ND	ND		ND	
Bromomethane	0.2	ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND	ND		ND	
Chloroform ^e	0.1	26	30	34	34	48	60	69
Bromodichloromethane ^e	0.1	27	32	34	36	45	64	68
Dibromochloromethane ^e	0.1	10	11	13	14	18	32	37
Bromoform ^e	0.25	1	1	2	2	1	3	2
THM4 ^f		64	74	83	86	112	159	176
Dichloriodomethane	0.5	ND	0.7	0.8	0.9	NR	1	NR
Bromochloriodomethane	0.5	ND	ND	ND	ND	NR	ND	NR
Dibromiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.1	ND	ND	ND	ND	ND	NR	NR
Carbon tetrachloride	0.2	ND	ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2	2.5	ND	ND	ND		2.3	
Monobromoacetic acid ^e	1	1.2	ND	ND	ND		1.2	
Dichloroacetic acid ^e	1	23	14	17	17		15	
Bromochloroacetic acid ^e	1	15	7.5	7.2	7.3		12	
Dibromoacetic acid ^e	1	3.3	1.5	2.8	2.9		4.1	
Trichloroacetic acid ^e	1	25	22	20	20		17	
Bromodichloroacetic acid	1	18	15	12	12		12	
Dibromochloroacetic acid	1	5.5	4.4	3.8	3.9		4.3	
Tribromoacetic acid	2	ND	ND	ND	ND		ND	
HAA5 ^h		55	38	40	40		40	
HAA9 ⁱ		94	64	63	63		68	
DXAA ^j		41	23	27	27		31	
TXAA ^k		49	41	36	36		33	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.2	0.9	0.9	0.9	0.9	NR	1	NR
Bromoacetonitrile	0.1	ND	0.1	0.2	0.1	0.1	ND	ND
Dichloroacetonitrile ^e	0.1	6	6	5	5	7	8	7
Bromochloroacetonitrile ^e	0.1	2	2	2	2	3	4	4
Dibromoacetonitrile ^e	0.1	2	1	0.6	1	0.9	2	2
Trichloroacetonitrile ^e	0.1	0.1	ND	0.1	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND	ND	ND				
Dibromochloroacetonitrile	0.5	ND	ND	ND				
Tribromoacetonitrile	0.90	ND	ND	ND				
<u>Haloketones</u>								
Chloropropanone	0.1	0.3	0.3	0.4	0.4	0.5	0.3	0.3
1,1-Dichloropropanone ^e	0.1	2	2	1	1	0.3	0.3	0.6
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	0.2	0.1	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.1	3	3	3	3	3	2	1
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	2	1	0.9	1	0.7	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	1	0.4	0.3	0.3	0.2	ND	ND
1,1,1,3-Tetrachloropropanone	0.1	0.2	0.3	0.1	0.1	0.1	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND

Table 15 (continued)

10/16/2001	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.22	5	5	3	4	4	2	2
Bromochloroacetaldehyde	0.5	2	2	1	1	2	1	1
Chloral hydrate ^e	0.1	9	9	7	8	12	15	8
Tribromoacetaldehyde	0.1	0.1	0.1	ND	ND	0.1	ND	ND
<u>Halonitromethanes</u>								
Chloronitromethane	0.1	0.4	0.4	0.2	0.2	ND	NR	NR
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	0.2	0.2
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	0.1	0.2	0.2	0.2	0.2	ND	0.2
Bromodichloronitromethane	0.5	ND	ND	ND				
Dibromochloronitromethane	0.5	ND	ND	ND				
Bromopicrin	0.5	ND	ND	ND				
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5	3	2	1	2		2	
Methyl <i>tertiary</i> butyl ether	0.2	0.8	1	1	1		1	
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.25	ND	ND	ND	ND	NR	ND	NR

Table 16. DBP results at plant 3 (1/28/02)

01/28/2002	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2	ND ^d		ND	ND	ND	ND		ND	
Bromomethane	0.2	ND		ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND		ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND		ND	ND	ND	ND		ND	
Chloroform ^e	0.2	ND	NR ^g	20	16	20 ^q	NR	NR	NR	NR
Bromodichloromethane ^e	0.2	ND	NR	4	6	7	8	NR	10	NR
Dibromochloromethane ^e	0.5	ND	NR	2	3	4	5	NR	4	NR
Bromoform ^e	0.5	ND	NR	ND	0.6	0.6	0.6	NR	0.7	NR
THM4 ^f		ND	NR	26	26	32	NR	NR	NR	NR
Dichloriodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloriodomethane	0.5	ND	NR	ND	ND	ND	ND	NR	ND	NR
Dibromiodomethane	0.5	ND	NR	ND	ND	ND	ND	NR	ND	NR
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
Bromodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	NR	ND
Iodoform	1.0	ND	NR	ND	ND	ND	ND	NR	ND	NR
Carbon tetrachloride	0.2	ND		ND	ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid ^e	2			ND	ND	2.5	2.8		2.7	
Monobromoacetic acid ^e	1			ND	ND	ND	ND		ND	
Dichloroacetic acid ^e	1			19	4.3	7.8	7.6		9.3	
Bromochloroacetic acid ^e	1			2.6	ND	1.6	1.5		5.2	
Dibromoacetic acid ^e	1			ND	ND	ND	ND		ND	
Trichloroacetic acid ^e	1			20	9.8	13	12		13	
Bromodichloroacetic acid	1			5.6	2.7	4.4	4.0		1.5	
Dibromochloroacetic acid	1			2.0	1.2	1.6	1.4		2.8	
Tribromoacetic acid	2			ND	ND	ND	ND		ND	
HAA5 ⁿ				39	14	23	22		25	
HAA9 ⁱ				49	18	31	29		35	
DXAA ^j				22	4.3	9.4	9.1		15	
TXAA ^k				28	14	19	17		17	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
Dichloroacetonitrile ^e	1	ND	NR	3	1	1	NR	NR	NR	NR
Bromochloroacetonitrile ^e	0.1	ND	NR	0.5	0.2	0.3	0.4	NR	1	0.7
Dibromoacetonitrile ^e	0.1	ND	ND	ND	ND	<0.5 ^o	<0.5	ND	<0.5	0.2
Trichloroacetonitrile ^e	0.5	ND	NR	ND	ND	ND	ND	NR	ND	NR
Bromodichloroacetonitrile	0.5	ND		ND	ND	ND				
Dibromochloroacetonitrile	0.5	ND		ND	ND	ND				
Tribromoacetonitrile	0.95	ND		ND	ND	ND				
Haloketones										
Chloropropanone	0.1	ND	0.1	0.3	0.3	0.3	0.3	0.4	NR	0.3
1,1-Dichloropropanone ^e	0.10	ND	0.4	1	0.7	0.7	0.6	0.2	1	NR
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
1,1,1-Trichloropropanone ^e	0.5	ND	ND	2	1	1	1	NR	1	NR
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
1-Bromo-1,1-dichloropropanone	1.0	ND	NR	1	ND	ND	<1 ^f	NR	ND	NR
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
1,1,3-Tribromopropanone	0.1	0.1	ND	0.2	0.1	ND	0.1	ND	NR	0.1
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	0.2	ND	ND	ND	ND	NR	0.2
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	NR	ND
1,1,3,3-Tetrabromopropanone	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR

Table 16 (continued)

01/28/2002	MRL ^a	Plant 3 ^b								
Compound	µg/L	Raw	Rapid Mix	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloacetaldehydes										
Dichloroacetaldehyde	0.98	ND	0.6	3	1	ND	ND	ND	NR	3
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND	NR	ND
Chloral hydrate ^e	0.1	0.3	0.2	3	0.8	0.9	0.9	ND	NR	4
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
Halonitromethanes										
Chloronitromethane	N/A	ND		ND	ND	ND	ND		ND	
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
Dichloronitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	NR	0.2
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	NR	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	0.5	ND	ND	ND	ND	<0.5	1
Bromodichloronitromethane	0.5	ND		0.5	ND	0.6				
Dibromochloronitromethane	0.5	ND		ND	ND	ND				
Bromopicrin	0.5	ND		ND	ND	ND				
Miscellaneous Compounds										
Methyl ethyl ketone	0.5	ND		ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2	0.6		0.6	0.6	0.6	0.7		0.7	
1,1,2,2-Tetrabromo-2-chloroethane	2.5	ND	NR	ND	ND	ND	ND	NR	ND	NR
Benzyl chloride	0.25	ND	NR	ND	ND	ND	ND	NR	ND	NR

^aResults in *italics* tentative due to problems with quality assurance^b<1: Detected by SPE-GC/MS, but below MRL for SPE-GC/MS

Table 17. DBP results at plant 4 (1/28/02)

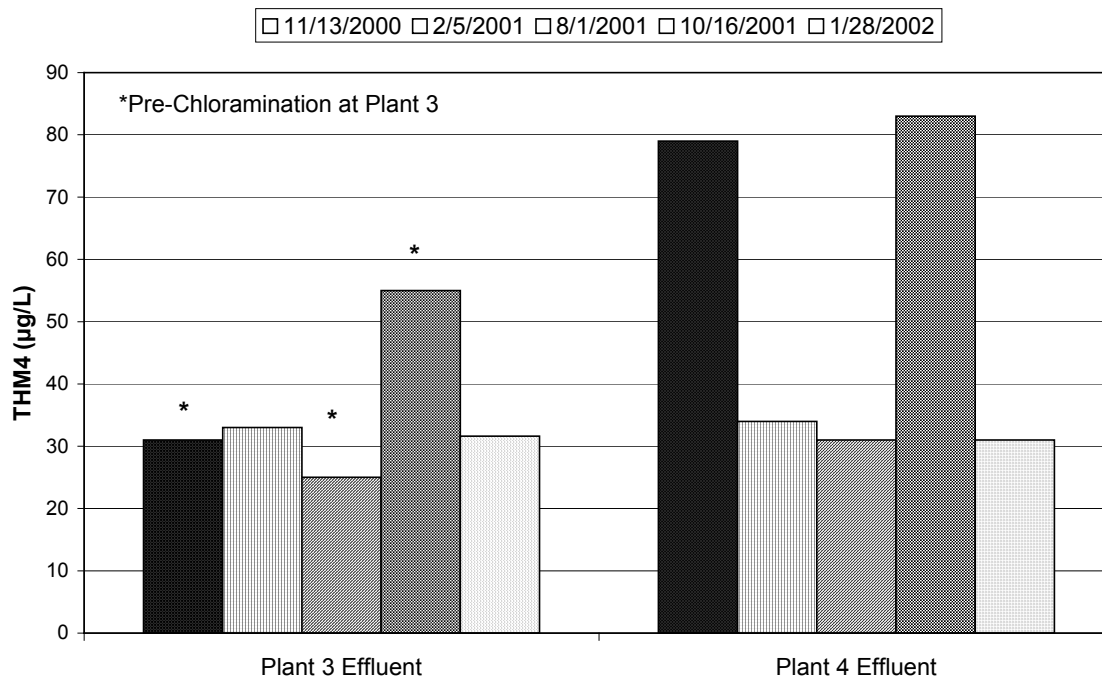
01/28/2002	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>								
Chloromethane	0.2	ND	ND	ND	ND		ND	
Bromomethane	0.2	ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND	ND		ND	
Chloroform ^e	0.2	20	20	20	NR	NR	NR	NR
Bromodichloromethane ^e	0.2	9	6	8	8	NR	11	NR
Dibromochloromethane ^e	0.5	3	2	3	2	NR	5	NR
Bromoform ^e	0.5	ND	ND	ND	ND	NR	ND	NR
THM4 ^f		32	28	31	NR	NR	NR	NR
Dichloriodomethane	0.5	ND	ND	ND	ND	ND	ND	ND
Bromochloriodomethane	0.5	ND	ND	ND	ND	NR	ND	NR
Dibromiodomethane	0.5	ND	ND	ND	ND	NR	ND	NR
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Iodoform	1.0	ND	ND	ND	ND	NR	ND	NR
Carbon tetrachloride	0.2	ND	ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2	2.3	2.6	ND	ND		2.5	
Monobromoacetic acid ^e	1	ND	ND	1.0	ND		ND	
Dichloroacetic acid ^e	1	21	21	17	16		19	
Bromochloroacetic acid ^e	1	3.3	3.2	2.6	2.4		3.5	
Dibromoacetic acid ^e	1	ND	ND	ND	ND		ND	
Trichloroacetic acid ^e	1	26	28	21	21		24	
Bromodichloroacetic acid	1	6.8	6.9	5.8	5.8		5.3	
Dibromochloroacetic acid	1	2.8	2.5	1.9	1.8		ND	
Tribromoacetic acid	2	ND	ND	ND	ND		ND	
HAA5 ^h		49	52	39	37		46	
HAA9 ⁱ		62	64	49	47		54	
DXAA ^j		24	24	20	18		23	
TXAA ^k		36	37	29	29		29	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	0.3	ND	ND	ND	ND	0.3	0.3
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	1	4	3	2	NR	NR	NR	NR
Bromochloroacetonitrile ^e	0.1	0.8	0.6	0.6	0.8	0.2	1	2
Dibromoacetonitrile ^e	0.1	0.3	ND	ND	<0.5	ND	0.3	0.4
Trichloroacetonitrile ^e	0.5	ND	ND	ND	ND	NR	ND	NR
Bromodichloroacetonitrile	0.5	ND	ND	ND			ND	
Dibromochloroacetonitrile	0.5	ND	ND	ND			ND	
Tribromoacetonitrile	0.95	ND	ND	ND			ND	
<u>Haloketones</u>								
Chloropropanone	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.2
1,1-Dichloropropanone ^e	0.1	2	1	0.7	0.5	0.8	0.6	0.5
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.5	4	3	3	3	NR	3	NR
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	1.0	<1	<1	<1	1	NR	ND	NR
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	0.3	0.2	ND	ND	ND	0.1	0.1
1,1,3,3-Tetrachloropropanone	0.10	0.1	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	N/A	NR	NR	NR	NR	NR	NR	NR

Table 17 (continued)

01/28/2002	MRL ^a	Plant 4 ^c						
Compound	µg/L	GAC Inf	GAC Eff	Plant Eff	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.98	2	3	1	1	1	1	1
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND
Chloral hydrate ^e	0.1	9	5	2	2	3	10	17
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Chloronitromethane	N/A	ND	ND	ND	ND		ND	
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	0.6	0.4	ND	ND	ND	0.7	1
Bromodichloronitromethane	0.5	0.6	0.6	0.5			0.7	
Dibromochloronitromethane	0.5	ND	ND	ND			ND	
Bromopicrin	0.5	ND	ND	ND			ND	
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5	ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2	0.6	0.7	0.6	0.7		0.7	
1,1,2,2-Tetrabromo-2-chloroethane	2.5	ND	ND	ND	ND	NR	ND	NR
Benzyl chloride	0.25	ND	ND	ND	ND	NR	ND	NR

Figure 4

Seasonal Variability in Trihalomethane Formation at Plants 3 and 4



Halomethanes. Figure 4 shows the seasonal variability in THM formation at plants 3 and 4. The sum of the four regulated THMs (THM4) ranged from 31 to 83 µg/L in the plant 4 effluent. The highest formation was in October 2001 when the bromide level was the highest. Note, during most sampling events, plant 4 effluent represented a blend of plant 4 and plant 3 waters. For example, in August 2001, the plant 4 effluent had 31 µg/L THM4. Based on a plant 4 flow of 11 mgd--with 37 µg/L THM4 in the GAC effluent--and the addition of 4.2 mgd of plant 3 GAC effluent--with 20 µg/L THM4--the theoretical THM4 for the plant 4 effluent was 32 µg/L. Because the plant 4 distribution system had a free chlorine residual, THM formation increased to 38-39 µg/L.

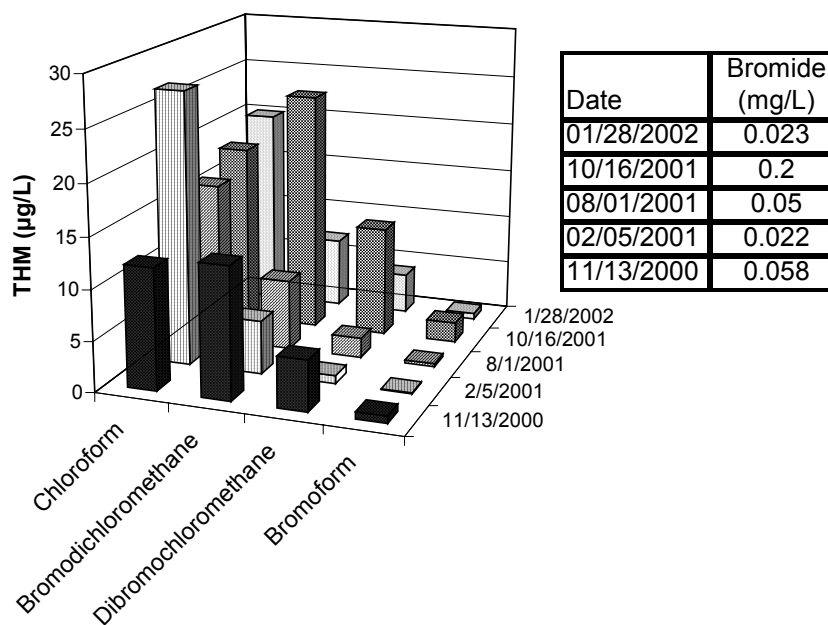
THM4 ranged from 25 to 55 µg/L in the plant 3 effluent. Pre-chloramination at plant 3 was more effective at minimizing THM formation in November 2000 than in October 2001, most likely due to the difference in bromide concentrations between these two periods (0.06 versus 0.2 mg/L, respectively). Pre-chloramination was not required in February 2001, as the water temperature (7-10°C) and bromide (0.02 mg/L) were relatively low during this time period. Thus, pre-chloramination was used at plant 3 at the times of the year in which THM formation would be too high with pre-chlorination (e.g., summer and fall).

Figure 5 shows the impact of bromide on THM speciation in plant 3 effluent. In October 2001, when the bromide level was the highest, there was the greatest shift in speciation to brominated THMs. In February 2001 and January 2002, when the bromide concentration was the lowest, chloroform was the major THM species formed.

In terms of iodinated THMs, dichloriodomethane was typically detected in some of the samples each quarter. When detected, the concentration of this iodinated THM ranged from 0.25 to 2 µg/L. In November 2000, bromodiiodomethane and iodoform were also detected in selected samples. Dichloriodomethane and/or bromochloriodomethane were also found using broadscreen-gas chromatography/mass spectrometry (GC/MS) methods (carried out by the USEPA) in finished water from plant 3 and plant 4.

Figure 5

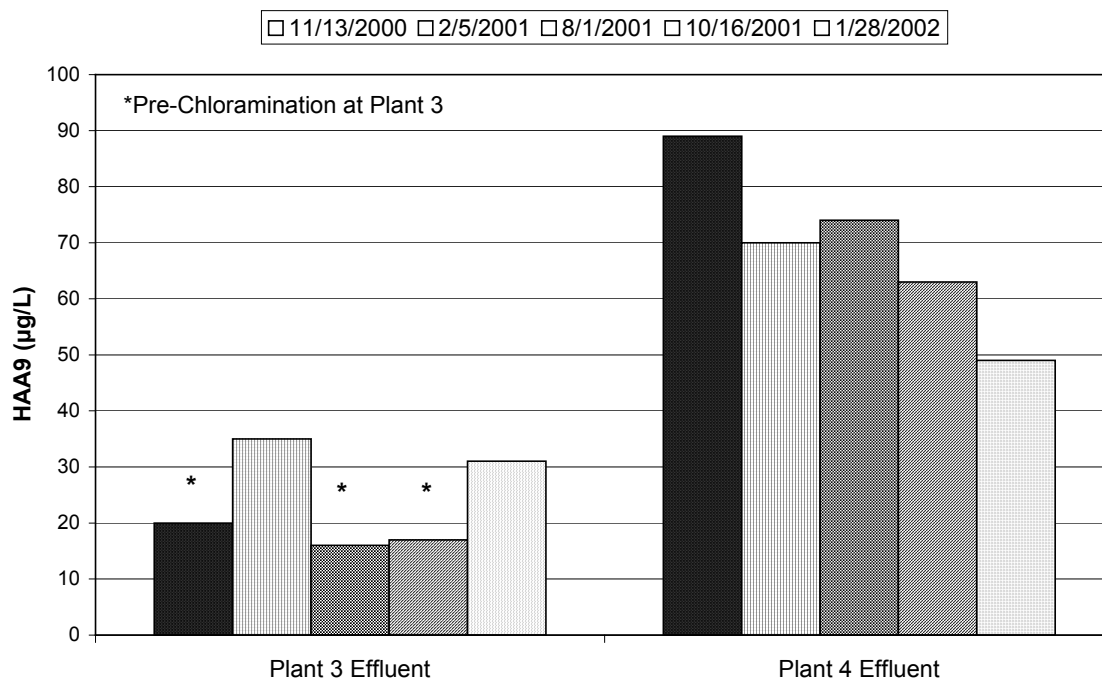
**Impact of Bromide on Trihalomethane Speciation
in Plant 3 Effluent**



Haloacids. Figure 6 shows the seasonal variability in haloacetic acid (HAA) occurrence at plants 3 and 4. The sum of the five regulated HAAs (HAA5) ranged from 39 to 66 µg/L in the plant 4 effluent. The sum of all nine species (HAA9) ranged from 49 to 89 µg/L. The plant 4 effluent typically represented a blend of plant 4 and plant 3 waters. For example, in August 2001, the plant 4 effluent had 61 µg/L HAA5 and 74 µg/L HAA9. Based on a plant 4 flow of 11 mgd before the addition of 4.2 mgd of plant 3 GAC effluent, the theoretical HAA5 and HAA9 for the plant 4 effluent was 65 and 76 µg/L, respectively. HAA5 and HAA9 were 8.4-32 and 17-35 µg/L, respectively, in the plant 3 effluent. The highest HAA occurrence in the plant 3 effluents was during the winter.

Figure 6

Seasonal Variability in Haloacetic Acid Occurrence at Plants 3 and 4



At plant 3, the concentration of HAA9 in the GAC influent was 36-61 µg/L, whereas the level in the GAC effluent ranged from not detected (ND) to 21 µg/L. Figure 7 shows that when the water temperature was warmer, HAAs were effectively removed, whereas when the water was colder, the removal of dihalogenated HAAs (DXAAs) was somewhat diminished and the removal of trihalogenated HAAs (TXAAs) was significantly impacted. GAC can provide a medium for biological activity, which can result in the control of HAAs. Other research has demonstrated that HAAs can be removed by GAC filtration, presumably by biodegradation processes within the filter bed (Singer et al., 1999). In another study, DXAAs were found to be much better biodegraded than TXAAs in a distribution system with no disinfectant residual, and the removal effectiveness was significantly impacted by water temperature (Baribeau et al., 2000).

In contrast, HAAs were typically not removed during GAC filtration at plant 4 (Figure 8), and when they were the percentage removed was much less than at plant 3. At plant 3, GAC was used in a post-filtration contactor, whereas at plant 4 GAC was used as a filter media in wood tub filters. In addition, there was little to no disinfectant residual in the plant 3 GAC effluents, whereas there was a free chlorine residual in the plant 4 GAC effluents. The operational use of GAC was different at the two plants.

Figure 7

Impact of Temperature on Removal
of Haloacetic Acids on Plant 3 GAC Filter

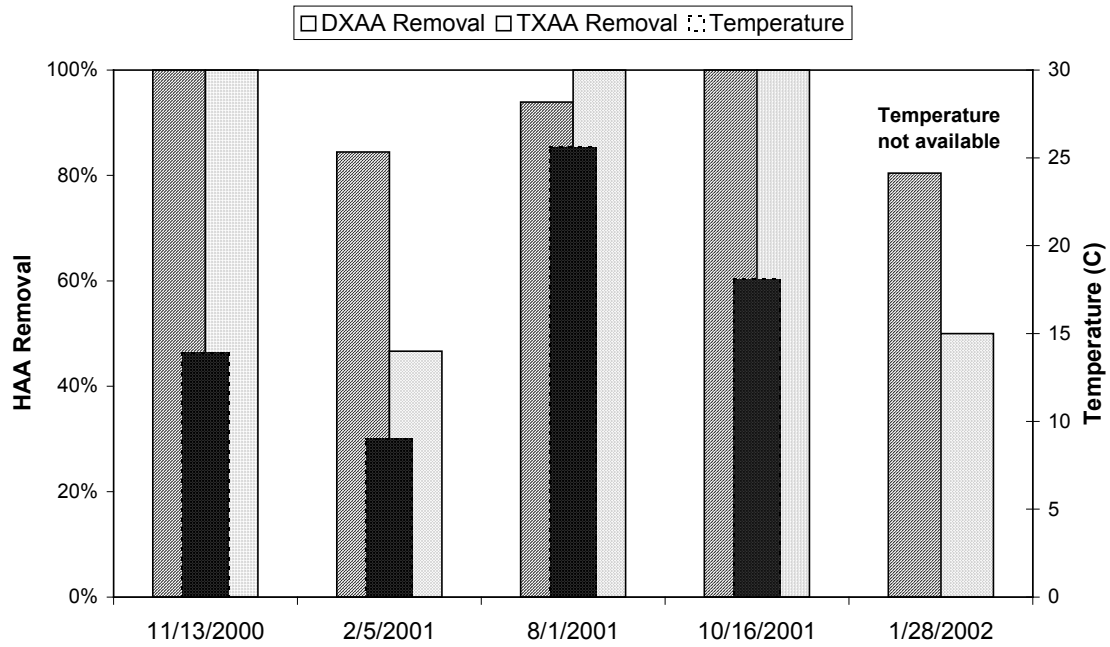


Figure 8

Impact of Temperature on Removal
of Haloacetic Acids on Plant 4 GAC Filter

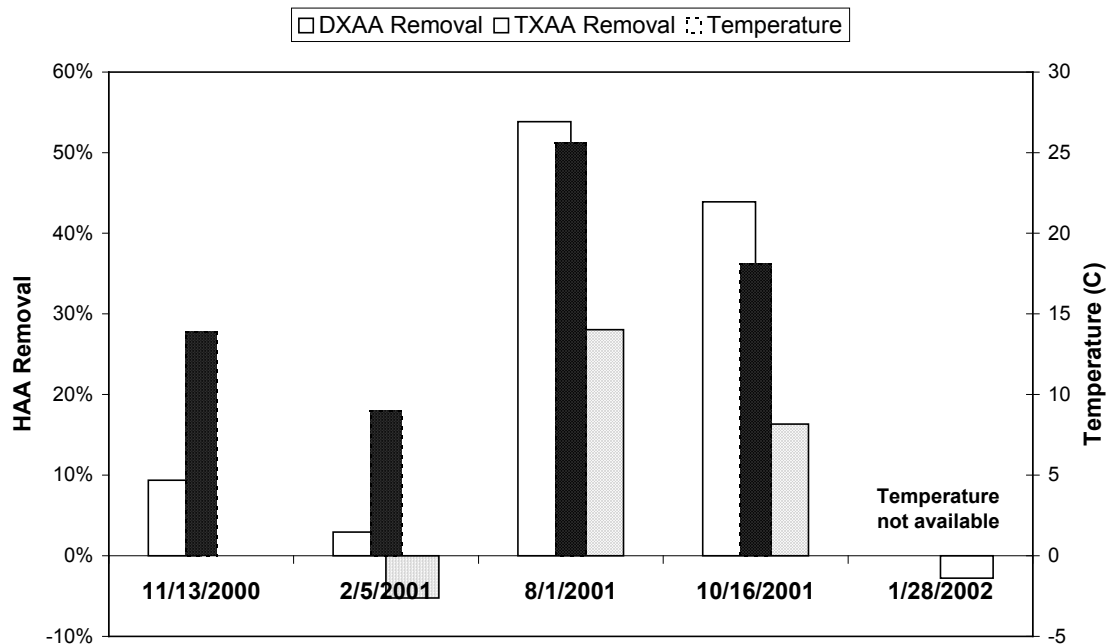


Figure 9 shows how HAAs were reformed during post-GAC chlorination, whereas THMs—which were not removed during GAC filtration—increased in formation through the treatment process. The levels of HAAs formed during post-GAC chlorination were less than what was initially formed by pre-chlor(am)ination. Because the HAAs were effectively removed by GAC during the warmer months, HAA occurrence in the plant effluent was primarily from the post-GAC chlorination. Alternatively, during the colder months, HAAs in the plant effluent were from a combination of HAAs not removed by GAC and that formed during post-GAC chlorination. Thus, HAA occurrence in the plant effluent was higher in the winter at plant 3.

Figure 9

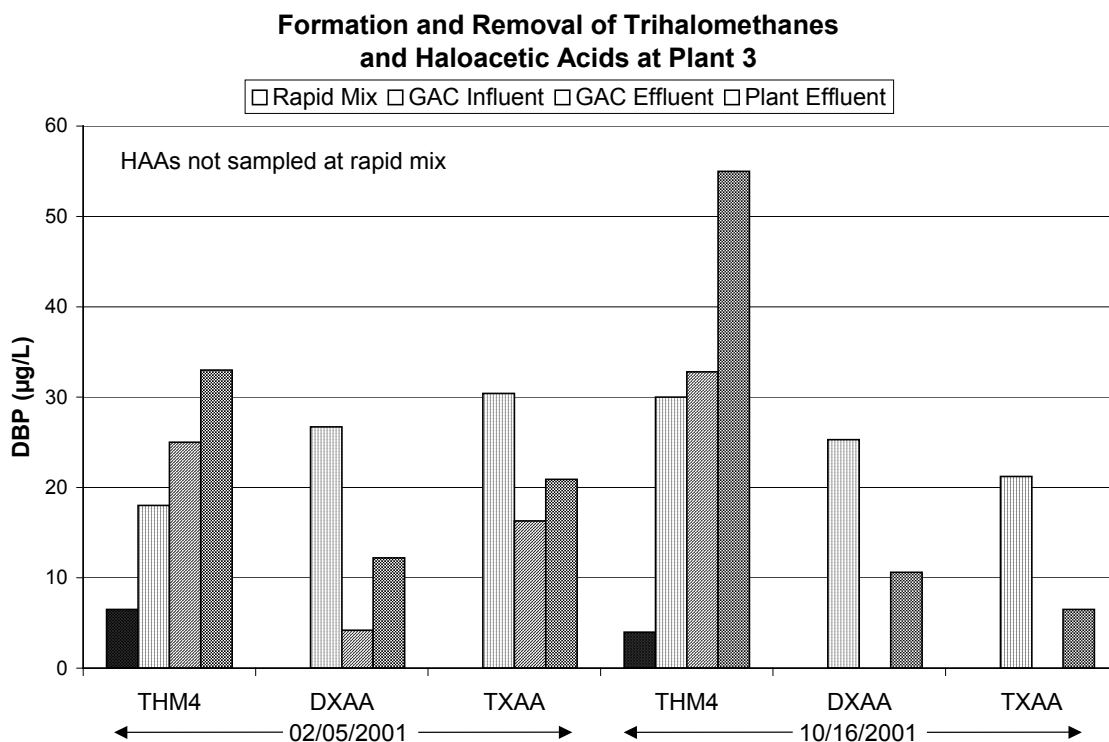


Figure 10 shows the impact of bromide on HAA speciation in the plant 3 GAC influent. In October 2001, when the bromide level was the highest, there was the greatest shift in speciation to brominated HAAs. In February 2001 and January 2002, when the bromide concentration was the lowest, dichloro- and trichloroacetic acid were the major HAA species formed.

Figure 10

**Impact of Bromide on Haloacetic Acid Speciation
in Plant 3 GAC Influent**

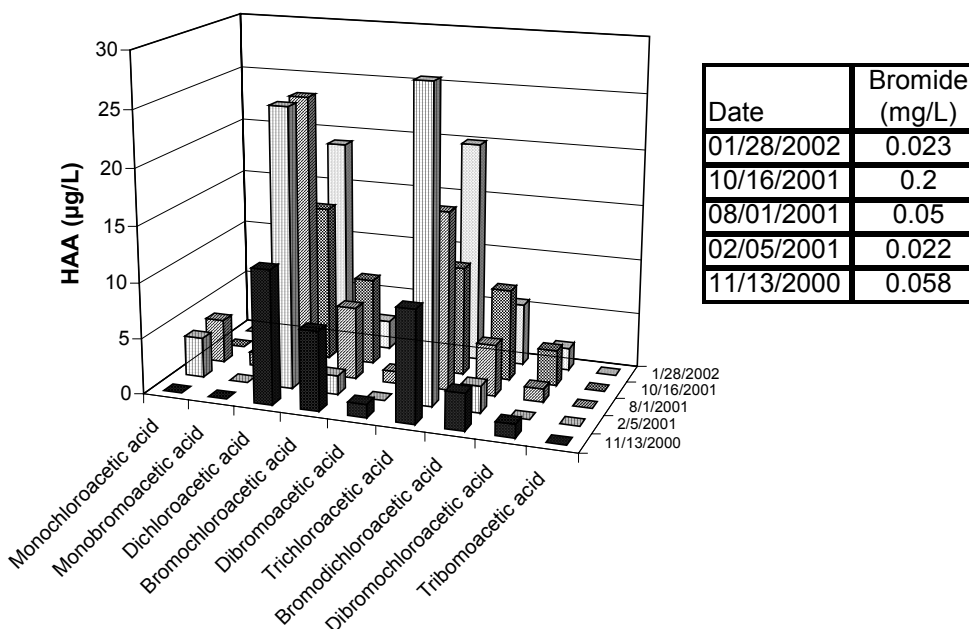
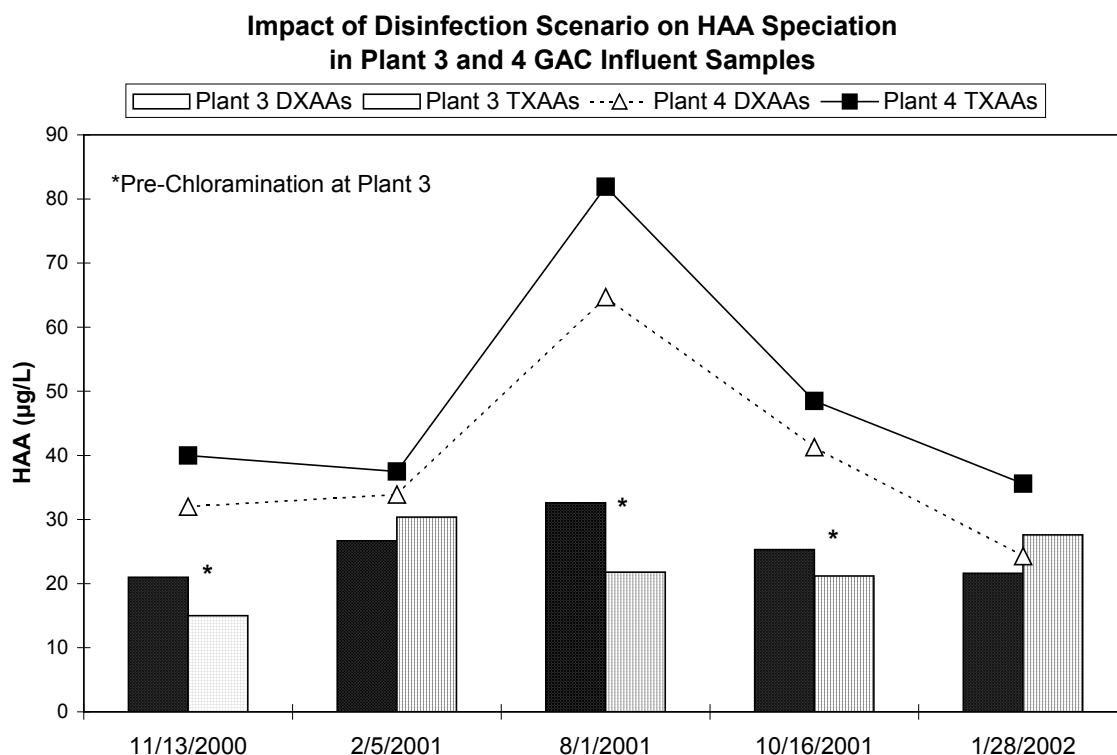


Figure 11 shows the impact of disinfection scenario on HAA speciation in plants 3 and 4 GAC influent samples. At plant 4, pre-chlorination resulted in the formation of more TXAAs than DXAAs. Likewise, Cowman and Singer (1996) found that the TXAAs were the dominant HAA species in their study during chlorination. At plant 3, during pre-chloramination, DXAAs were formed to a higher extent than the TXAAs. Krasner and co-workers (1996) found that chloramines minimized the formation of THMs and TXAAs better than that of DXAAs. Likewise, Cowman and Singer (1996) found that DXAAs were the principal HAA species formed from chloramination.

February 2001 results from UNC also show the presence of another target halo-acid, 3,3-dichloropropenoic acid, at levels of 1.5 and 0.9 µg/L, respectively, in finished waters from plant 3 and plant 4 (Table 18). 3,3-Dichloropropenoic acid, as well as trichloropropenoic acid, was also identified in broadscreen GC/MS analyses carried out by the USEPA.

Figure 11



Haloacetonitriles. In other research, haloacetonitriles (HANs) have been found to be produced at approximately one-tenth the level of the THMs (on a weight basis) (Krasner et al., 1989). In the latter study, the 25th and 75th percentile ratios of HANs to THMs were 0.065 and 0.147, respectively. The HAN to THM relationship had originally been established between dichloroacetonitrile (DCAN) and chloroform (trichloromethane [TCM]) (Oliver, 1983).

Figure 12 shows that DCAN formation in GAC influent samples at plants 3 and 4 was equal to or higher than one-tenth the level of chloroform. A linear regression of the data, except for the August 2001 data that were atypical, indicated that DCAN was ~17 % of the level of chloroform. This value was somewhat higher than the 75th percentile ratio observed by Krasner and colleagues (1989).

In these samples, the pH ranged from 5.5 to 6.2. In other research, THM formation has been shown to be lower at acidic pH and DCAN formation has been higher at acidic pH, whereas dichloroacetic acid (DCAA) formation was found to be relatively insensitive to pH (Stevens et al., 1989). Figure 13 shows the relationship between DCAN and DCAA formation for these samples. A linear regression of the data, including the August 2001 samples, indicated that DCAN was ~18 % of the level of DCAA. These results suggest that the pH of chlorination within plants 3 and 4 was, in part, impacting the relative formation of DCAN, chloroform, and DCAA.

Figure 12

Dichloroacetoneitrile (DCAN) Formation as a Function of Chloroform (TCM) Formation in Plants 3 and 4 GAC Influent Samples

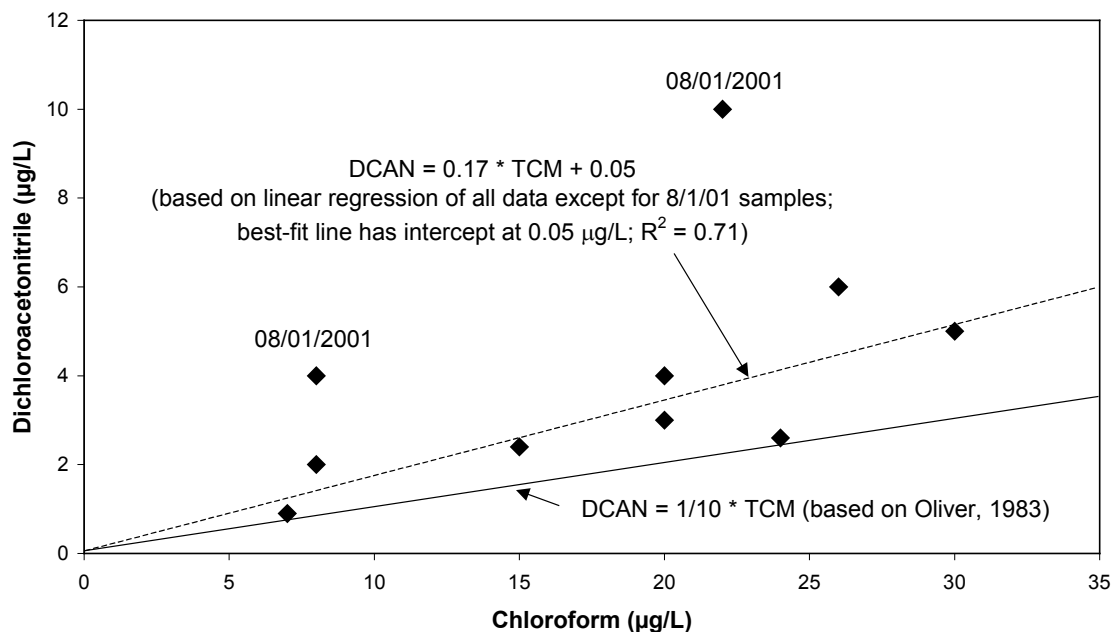
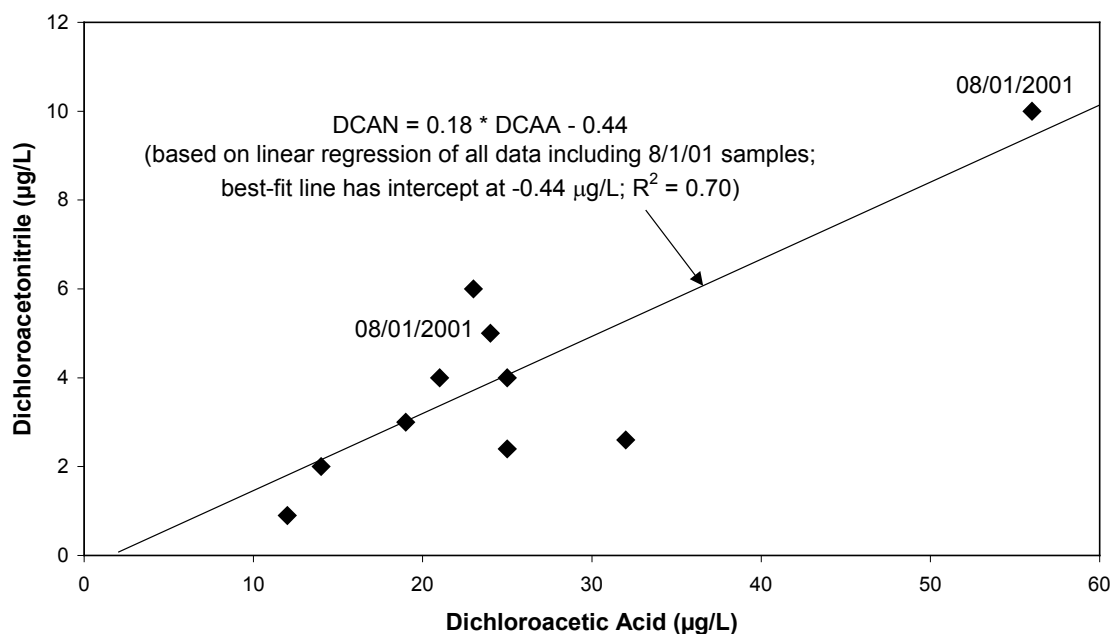


Figure 13

Dichloroacetoneitrile (DCAN) Formation as a Function of Dichloroacetic Acid (DCAA) Formation in Plants 3 and 4 GAC Influent Samples



DCAN was 0.9-4 and 0.1-1.6 µg/L in the plant 3 GAC influent and effluent, respectively. Figure 14 shows that the concentration of DCAN was significantly reduced in passing through the GAC when the water temperature was warm. DCAN was 2.6-10 and 2.8-10 µg/L in the plant 4 GAC influent and effluent, respectively. The level of DCAN was generally unchanged in passing through the plant 4 GAC filters (Figure 14). Likewise, the brominated analogues of DCAN were reduced in concentration in passing through the plant 3 GAC filter when the water temperature was warm, whereas the plant 4 GAC filters had no significant impact. Similar to the HAAs, the plant 3 GAC filter resulted in a significant reduction in the concentration of the HANs, and the phenomenon was temperature sensitive, whereas the plant 4 GAC filter did not significantly reduce the concentration of the HANs.

Figure 15 shows the impact of bromide on HAN speciation in plant 3 GAC influent. In October 2001, when the bromide level was the highest, there was the greatest shift in speciation to brominated HANs. In February 2001 and January 2002, when the bromide concentration was the lowest, DCAN was the major HAN species formed.

The plant 4 effluent typically represented a blend of plant 4 and plant 3 waters. For example, in August 2001, the plant 4 effluent had 6 µg/L DCAN. Based on a plant 4 flow of 11 mgd before the addition of 4.2 mgd of plant 3 GAC effluent, the theoretical DCAN concentration for the plant 4 effluent was 7 µg/L.

Finally, sub-µg/L levels of one of the EPA study HANs (i.e., chloroacetonitrile) were detected in selected samples. Broadscreen GC/MS analyses also revealed the presence of tribromoacetonitrile in one sample (finished water from plant 3, November 2000).

Haloketones. Figure 16 shows the impact of bromide on haloketone (HK) speciation in plants 3 and 4 GAC influent samples. Specifically, the two HK species in the Information Collection Rule (ICR) (1,1-dichloro- and 1,1,1-trichloropropanone) were evaluated along with two brominated analogues included in the EPA DBP study (1,1-dibromo- and 1-bromo-1,1-dichloropropanone). In October 2001, when the bromide level was the highest, there was an increase in the formation of both of these brominated HKs when compared to the August 2001 sampling, which was accompanied by decreases in the concentrations of the corresponding chlorinated species.

In addition to the formation of selected brominated species, other EPA study HKs (e.g., chloro-, 1,1,3-trichloro-, 1,1,3,3-tetrachloro-, and 1,1,1,3-tetrachloropropanone) were detected in selected samples. Furthermore, pentachloropropanone and hexachloropropanone were detected at plants 3 and 4 in November 2000, August 2001, and January 2002 by the USEPA using broadscreen-GC/MS methods.

Figure 14

Impact of Temperature on Removal
of Dichloroacetonitrile on GAC Filters

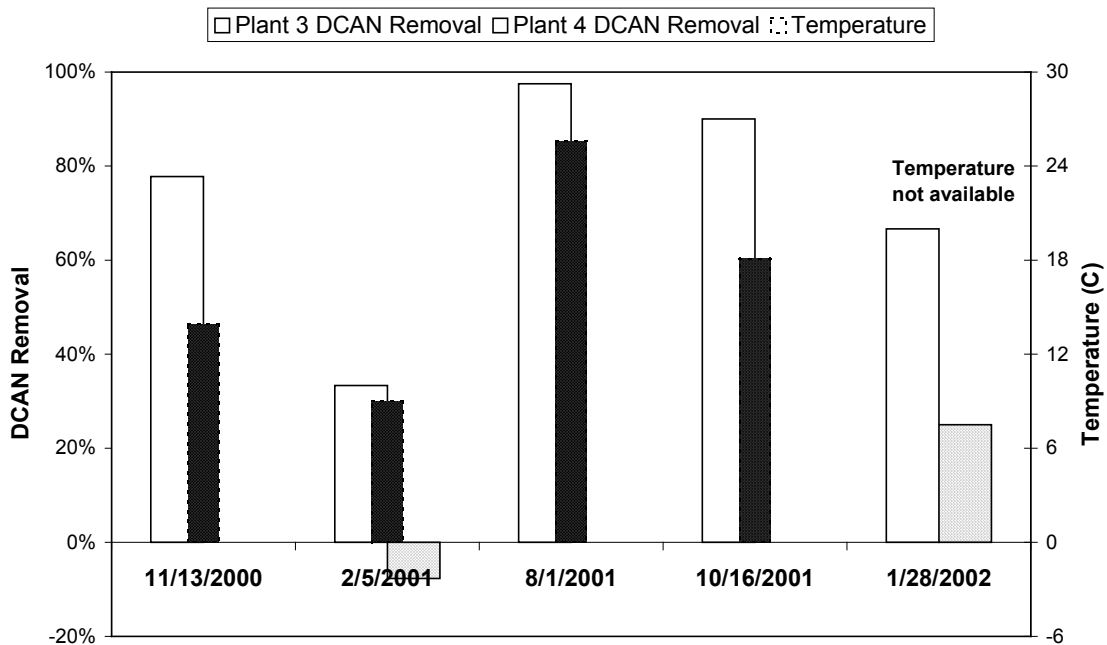


Figure 15

Impact of Bromide on Haloacetonitrile Speciation
in Plant 3 GAC Influent

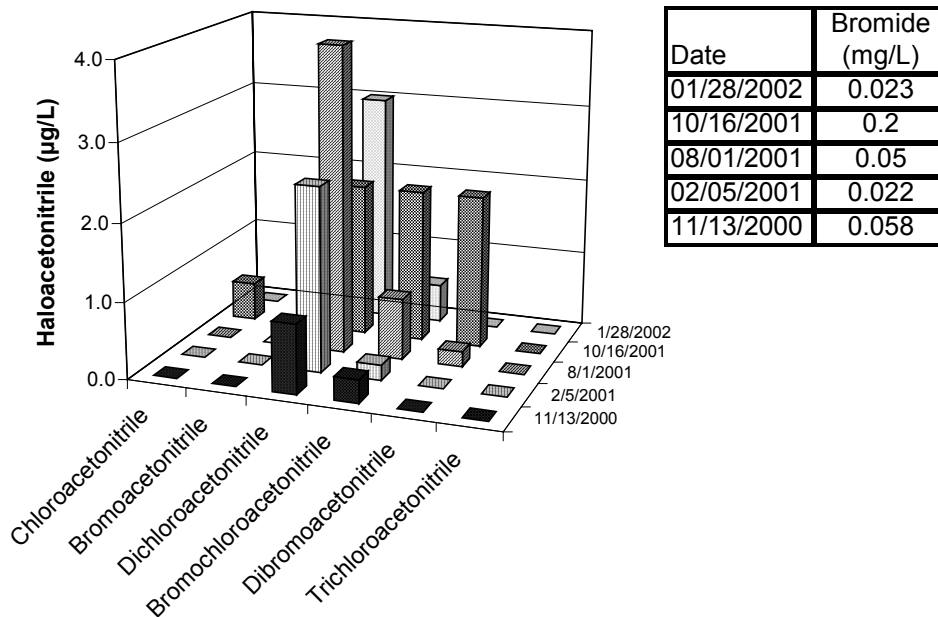


Figure 16. Impact of bromide on haloketone speciation in plants 3 and 4 GAC influent samples: bromide = 0.05 and 0.2 mg/L on 8/1/01 and 10/16/01, respectively.

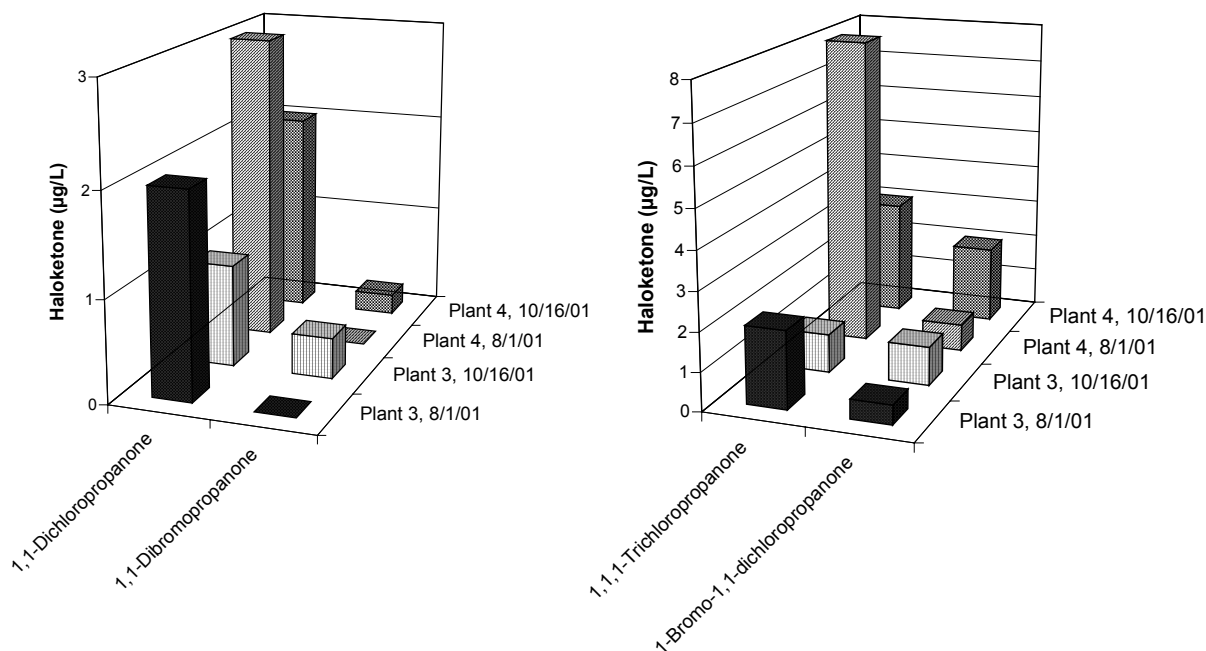


Figure 17 shows that the concentrations of 1,1-dichloro- and 1,1,1-trichloropropanone were significantly reduced in passing through the GAC when the water temperature was warm. The levels of these two HKs were generally unchanged in passing through the plant 4 GAC filters (Figure 18). Likewise, many of the EPA DBP study HKs were reduced in concentration in passing through the plant 3 GAC filter when the water temperature was warm, whereas the plant 4 GAC filters had no significant impact. Similar to the HAAs, the plant 3 GAC filter resulted in a significant reduction in the concentration of many of the HKs, and the phenomenon was temperature sensitive, whereas the plant 4 GAC filter did not significantly reduce the concentration of the HKs.

Figure 19 shows how most HKs that were reduced in concentration in the plant 3 GAC filter were reformed during post-GAC chlorination, whereas chloropropanone—which was not removed during GAC filtration—increased somewhat in concentration through the treatment process. The levels of HKs formed during post-GAC chlorination were less than what was initially formed by pre-chlor(am)ination.

Figure 17

Impact of Temperature on Removal
of Haloketones on Plant 3 GAC Filter

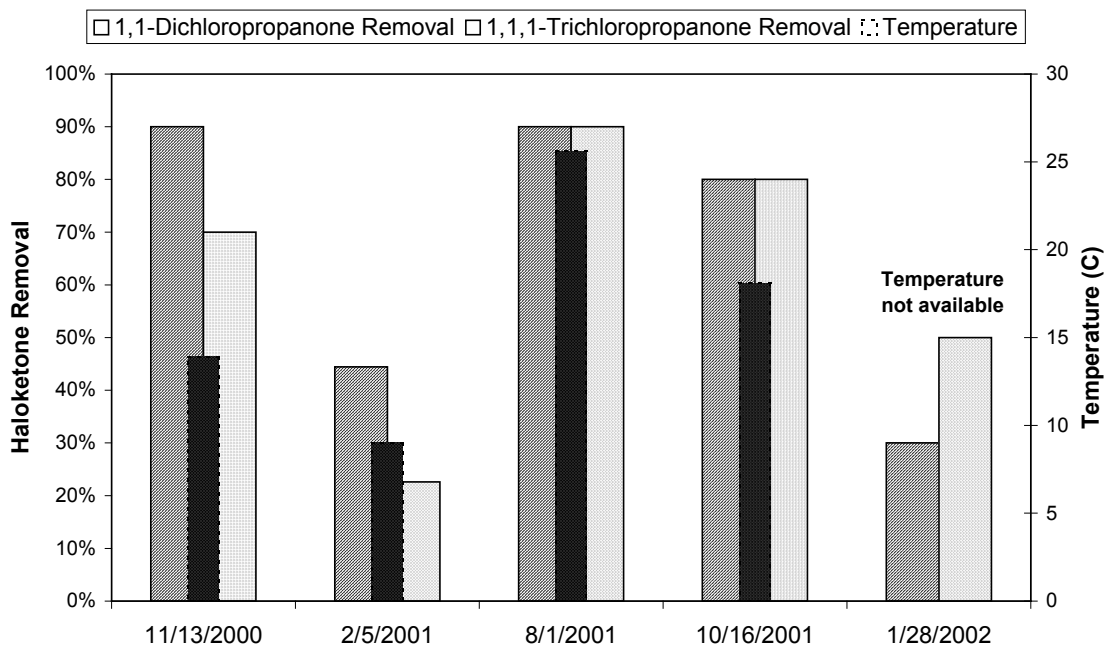


Figure 18

Impact of Temperature on Removal
of Haloketones on Plant 4 GAC Filter

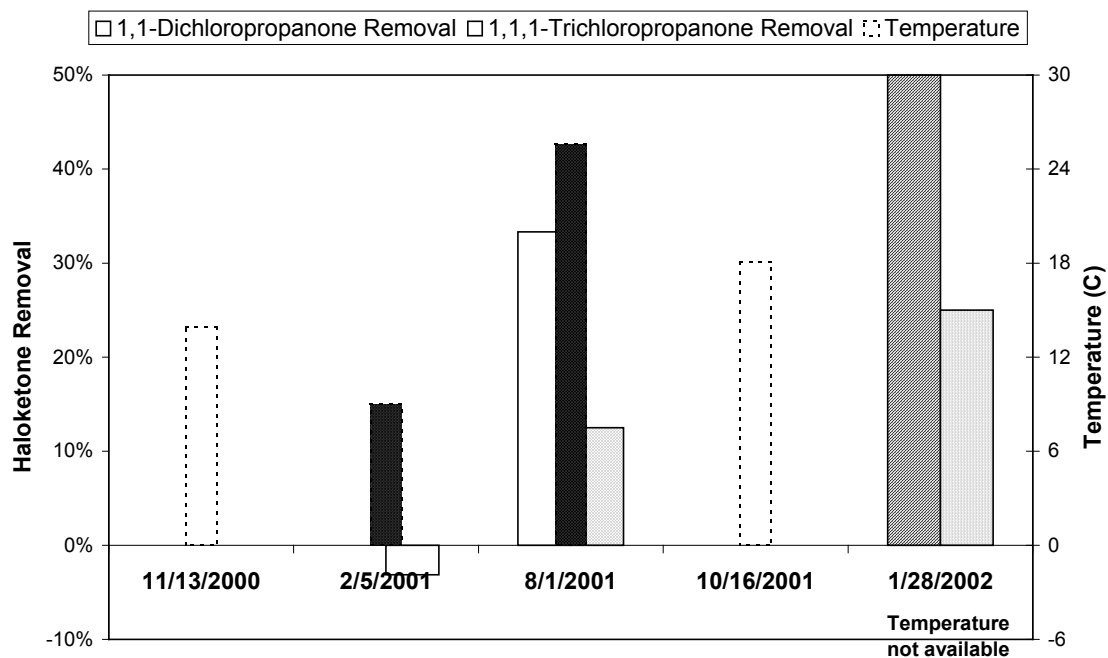
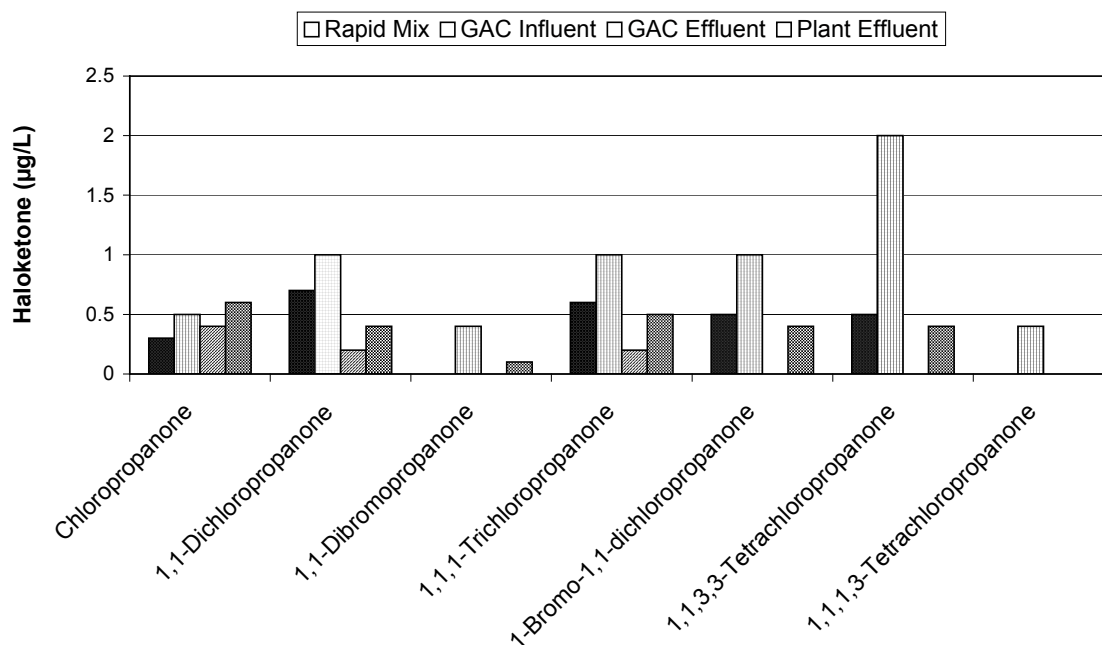


Figure 19

**Formation and Removal of Haloketones
at Plant 3: 10/16/01**



Haloacetaldehydes. Figure 20 shows the impact of bromide on haloacetaldehyde speciation in the plant 3 GAC influent. Note, the results for chloral hydrate in November 2000 represented the sum of the concentrations of chloral hydrate and bromochloroacetaldehyde, as these two DBPs co-eluted with the originally used GC method. In October 2001, when the bromide level was the highest, there was a significant formation of bromochloro- and tribromoacetaldehyde. In August 2001, there was also a significant formation of these two brominated haloacetaldehydes. Although the bromide concentration was lower in August, the higher water temperature combined with the bromide probably contributed to the formation of these brominated DBPs in that month. In February 2001 and January 2002, when the bromide concentration was the lowest, both brominated species were formed at very low levels or were not detected. In addition, another brominated aldehyde (2-bromo-2-methylpropanal) was detected at plant 3 in November 2000 by the USEPA using broad-screen GC/MS methods.

Figure 21 shows the impact of disinfection scenario on haloacetaldehyde speciation in plants 3 and 4 GAC influent samples. At plant 4, pre-chlorination resulted in the formation of more trihalogenated acetaldehydes than dihalogenated acetaldehydes. At plant 3, during pre-chloramination, dihalogenated acetaldehydes were typically formed to a higher extent than the trihalogenated acetaldehydes. Note, because bromochloroacetaldehyde results in November 2000 were included in the chloral hydrate (trichloroacetaldehyde) results due to co-elution on the GC, the speciation in that month could not be properly resolved.

Figure 20

**Impact of Bromide on Haloacetaldehyde Speciation
in Plant 3 GAC Influent**

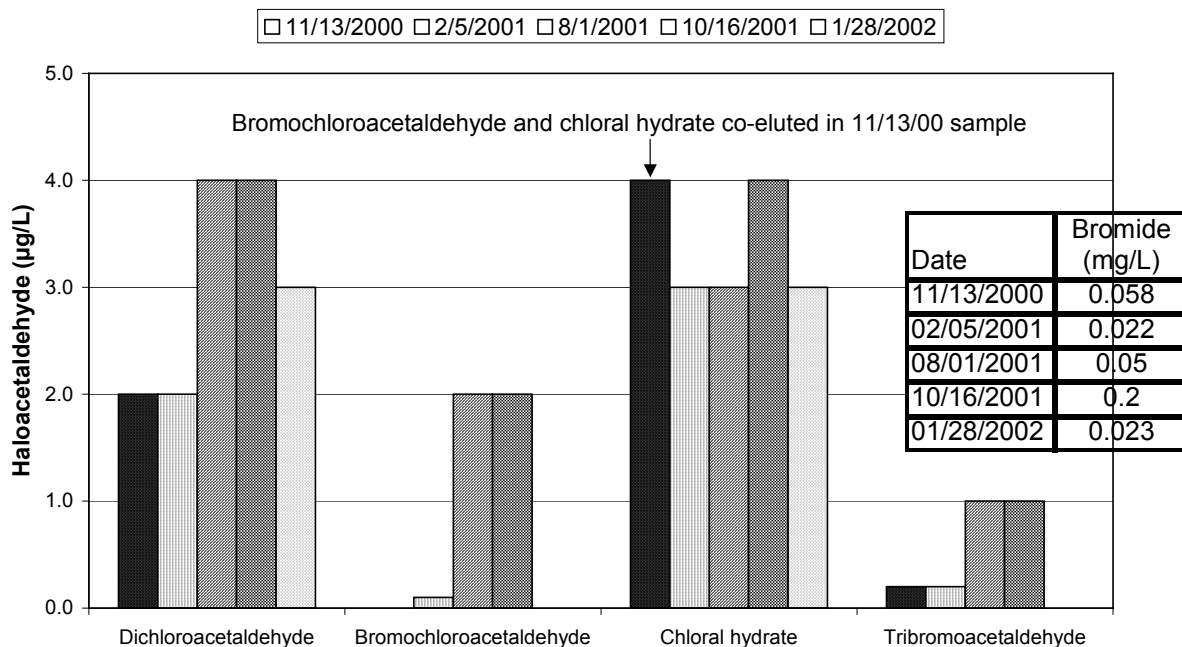
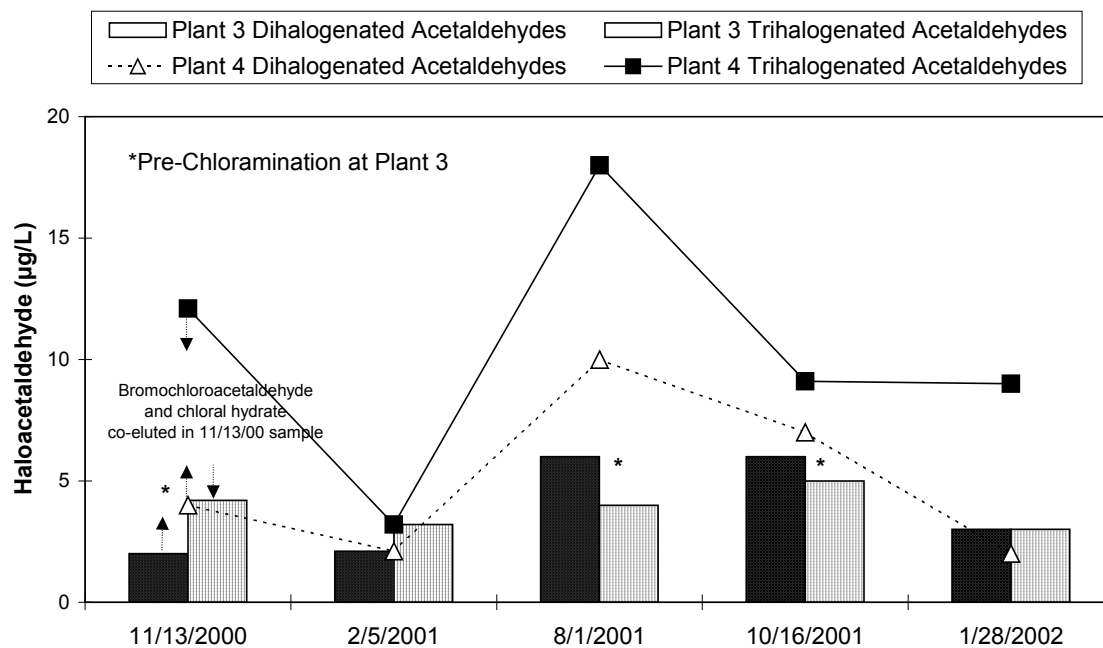


Figure 21

**Impact of Disinfection Scenario on Haloacetaldehyde Speciation
In Plants 3 and 4 GAC Influent Samples**



Young and colleagues (1995) observed that chloral hydrate production was minimized by chloramination, whereas the formation of DCAN was similar during chlorination and chloramination, and where DCAN was produced from the reaction of chloramines with reaction by-products such as dichloroacetaldehyde. The relative formation of di- and trihalogenated acetaldehydes with pre-chlorination versus pre-chloramination was similar to that observed for DXAAs and TXAAs (Figure 11).

Figure 22 shows that the concentrations of dichloroacetaldehyde and chloral hydrate were significantly reduced in passing through the GAC when the water temperature was warm. The levels of these two haloacetaldehydes were generally unchanged in passing through the plant 4 GAC filters (Figure 23). Likewise, the brominated haloacetaldehydes were reduced in concentration in passing through the plant 3 GAC filter when the water temperature was warm, whereas the plant 4 GAC filters typically had no significant impact. Similar to the HAAs, the plant 3 GAC filter resulted in a significant reduction in the concentration of the haloacetaldehydes, and the phenomenon was temperature sensitive, whereas the plant 4 GAC filter typically did not significantly reduce the concentration of the haloacetaldehydes.

Figure 22

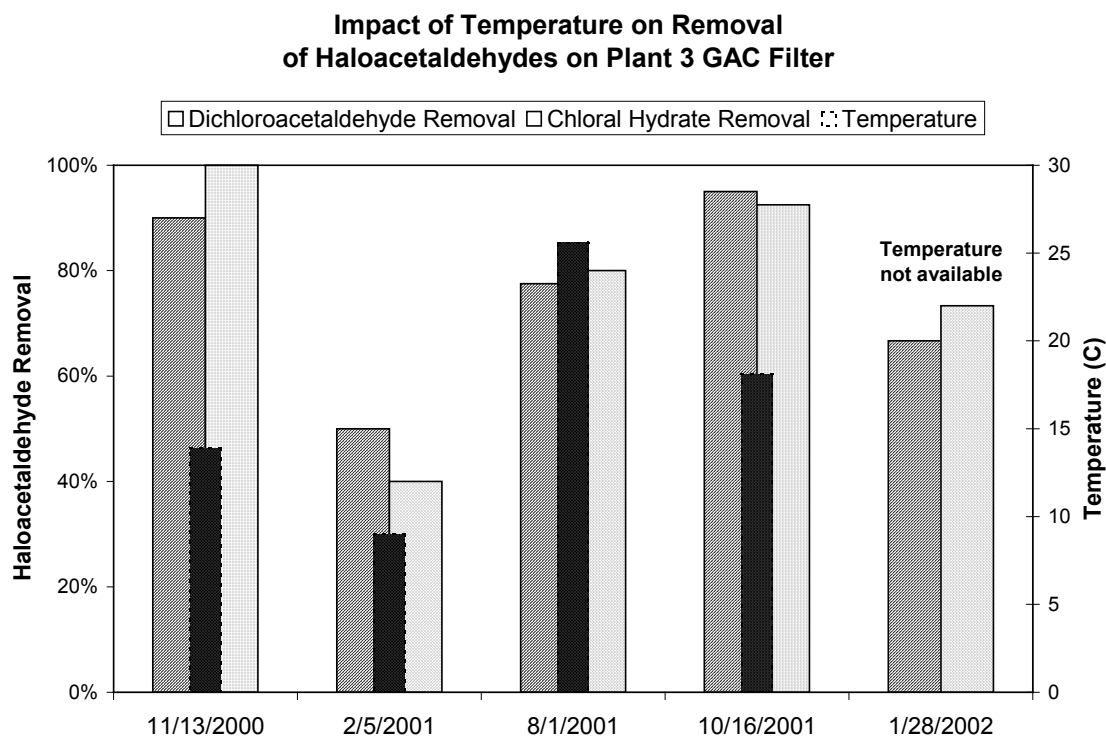


Figure 23

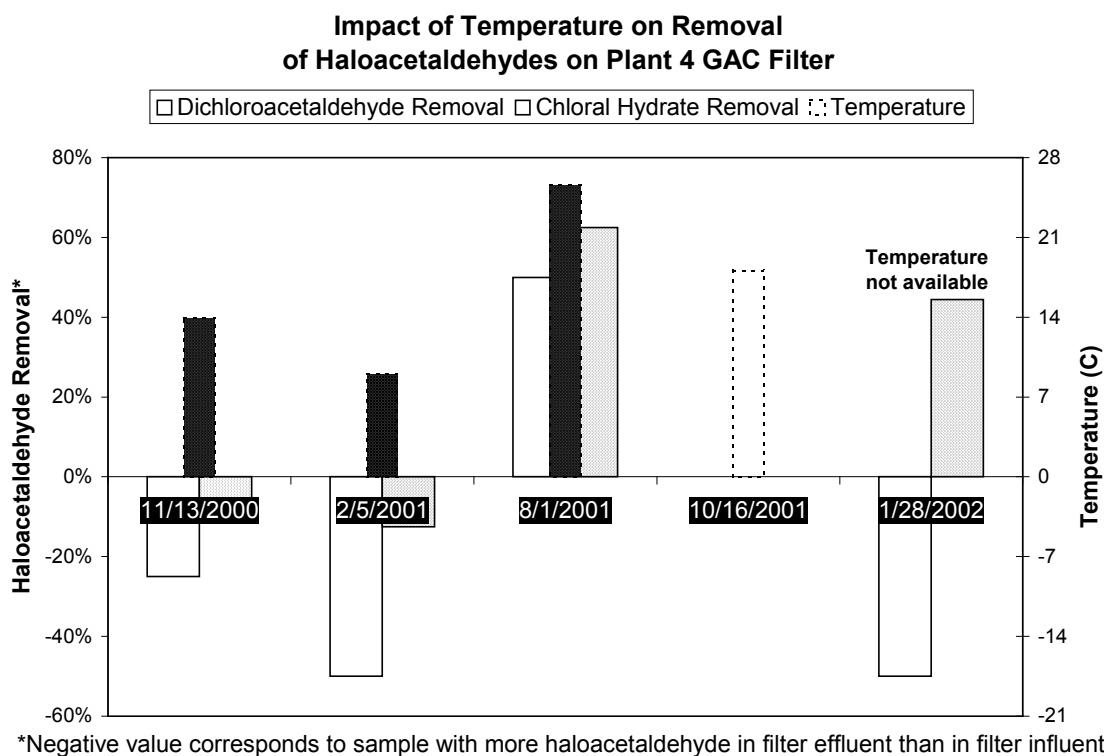
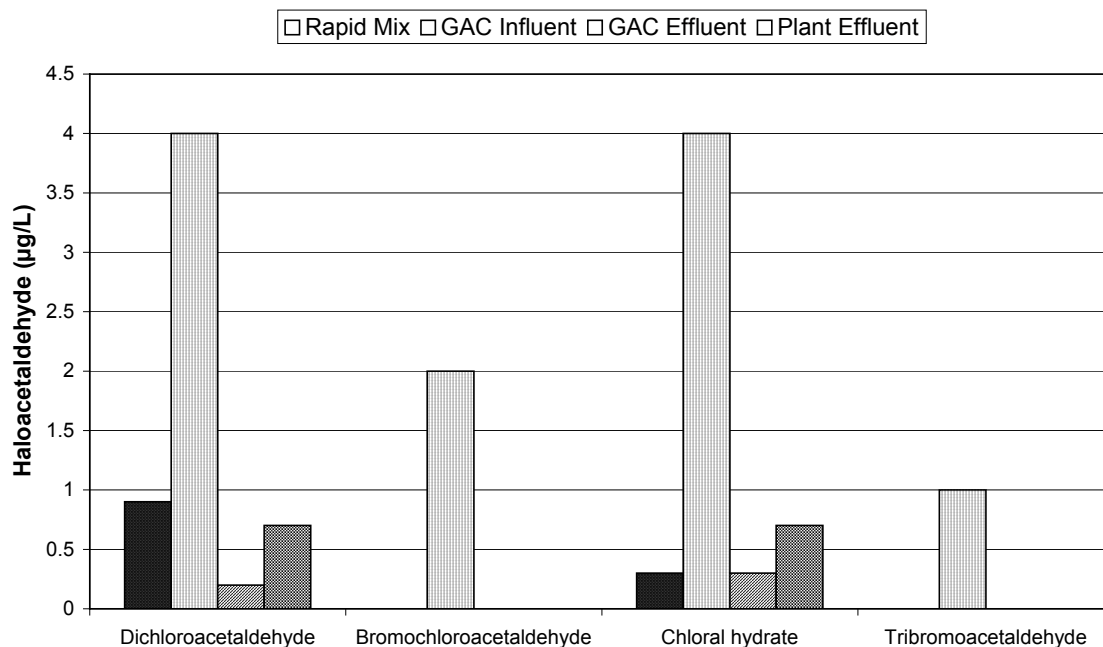


Figure 24 shows how some of the haloacetaldehydes were reformed during post-GAC chlorination at plant 3. The levels of haloacetaldehydes formed during post-GAC chlorination were less than what was initially formed by pre-chlor(am)ination.

Broadscreen analyses carried out at the USEPA also revealed the presence of four haloaldehydes that were not among the targeted list (Table 21). These are tentatively identified as 2-bromo-2-methylpropanal, iodobutanal, dichloropropenal, and 4-chloro-2-butenal. The identification of iodobutanal represents the first time that an iodinated aldehyde has been identified as a DBP. This compound was not present in the mass spectral library databases, but high resolution electron ionization (EI) mass spectrometry confirmed the empirical formula assignment of C_4H_7OI (molecular weight of 198). An exact isomer assignment for this molecule was not possible from the MS data obtained.

Figure 24

**Formation and Removal of Haloacetaldehydes
at Plant 3: 10/16/01**



Halonitromethanes. Sub-µg/L levels of chloropicrin (trichloronitromethane) were detected in selected samples. Dichloronitromethane was detected in selected samples in October 2001 and in January 2002. Brominated analogues of chloropicrin were detected in the plant 3 GAC influent in October 2001 when the bromide concentration was the highest (Figure 25). Because the occurrence of these DBPs were typically at or near their minimum reporting levels (MRLs), it was not possible to study their fate through the GAC filters on most sample dates. However, the data from February 2001 (Figure 26) suggest that chloropicrin was removed during GAC filtration at plant 3, not plant 4, even though the water temperature was relatively cold. Dichloronitromethane was also detected in finished water in August 2001 using broadscreen GC/MS techniques.

Figure 25

**Impact of Bromide on Halonitromethane Speciation in Plant 3 GAC Influent:
Bromide = 0.02 and 0.2 mg/L on 1/28/02 and 10/16/01, Respectively**

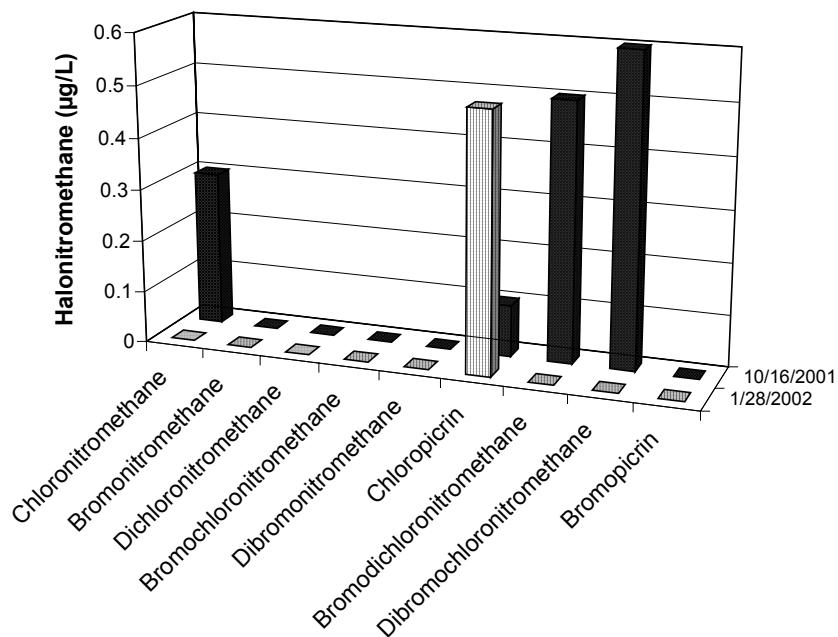
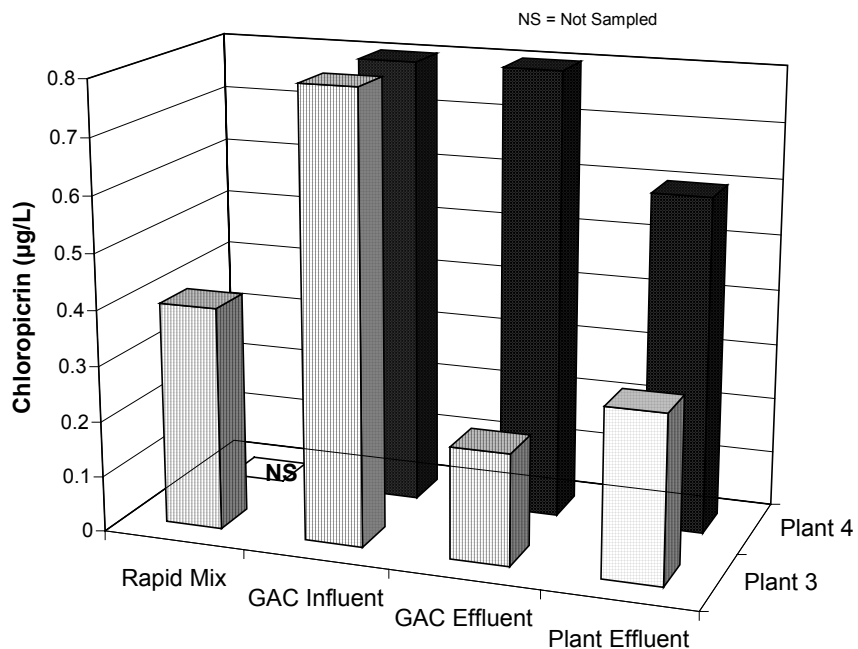


Figure 26

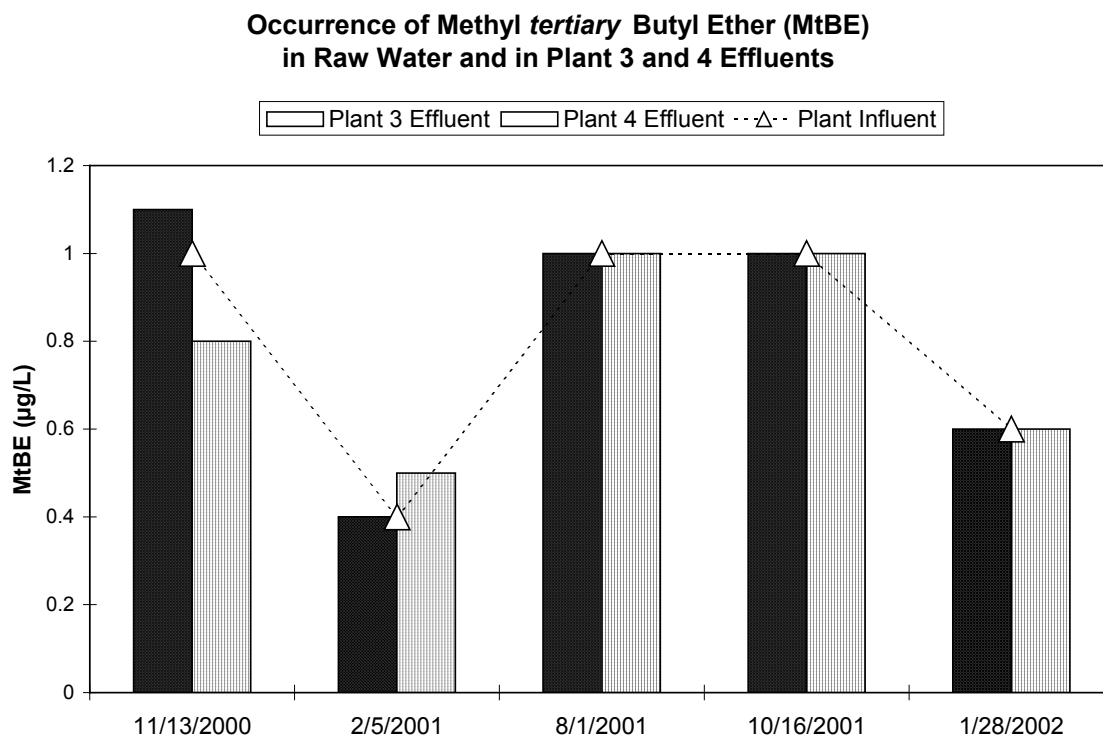
**Formation and Removal of Chloropicrin
at Plants 3 and 4: 2/5/01**



Volatile Organic Compounds (VOCs). Carbon tetrachloride, which is a VOC and a possible DBP, was detected (0.3-0.8 µg/L) at both plants in November 2000, but was not found in the raw water (MRL = 0.06 µg/L). As mentioned in a previous chapter, carbon tetrachloride has been detected by some utilities in gaseous chlorine cylinders (EE&T, 2000), due to imperfections in the manufacturing process or improper cleaning procedures.

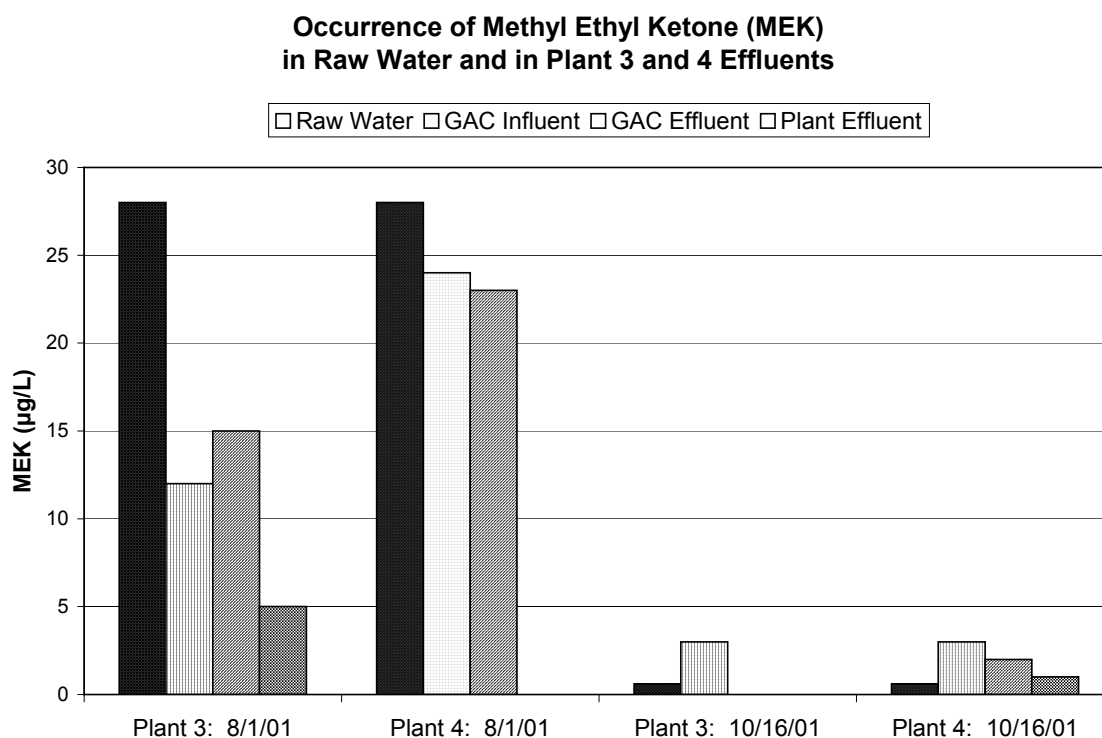
Methyl *tertiary* butyl ether (MtBE) was detected in the raw water on all of the sample dates, with concentrations of 0.4 to 1 µg/L (Figure 27). The level of MtBE was unchanged through either treatment plant. GAC at plant 3 did not remove MtBE. MtBE is a VOC (e.g., a gasoline additive), not a DBP, but is of concern due to widespread contamination of source waters.

Figure 27



Methyl ethyl ketone (MEK) was detected in the raw water on August 1, 2001 at a concentration of 28 µg/L (Figure 28). The level of MEK decreased through both treatment plants. MEK is an industrial solvent. The tremendous amount of rainfall the weekend before the sampling may have contributed to the presence of this solvent in the raw water (e.g., due to runoff). MEK was detected in the raw water on October 16, 2001 at 0.6 µg/L. After pre-chlor(am)ination, the level of MEK was 3 µg/L. MEK is also a DBP (an oxidation by-product). MEK was removed on the plant 3 GAC in October 2001, but only a small percentage of it was removed on the plant 4 GAC. MEK is a carbonyl, and various carbonyls have been shown to be biodegradable on biologically active filters (Krasner et al., 1993).

Figure 28



Halogenated Furanones. Table 20 presents data for 3-chloro-4-(dichloromethyl)-5-hydroxy-2[5H]-furanone, otherwise known as MX; (E)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid, otherwise known as EMX; and mucochloric acid (MCA), which can be found as a closed *ring* or in an *open* form. In October 2001, MX was detected at 0.18 µg/L (180 ng/L) in the finished water of plant 3 (which used chlorine-chloramine disinfection), which was higher than levels reported in a survey of Australian waters (<90 ng/L) (Simpson and Hayes, 1998). However, water quality and treatment/disinfection schemes may be different in Australia than in the United States. In particular, regulatory requirements in Australia are significantly different than in the United States. Subsequently, MX levels dropped in the distribution system to 0.013 µg/L (13 ng/L). EMX levels were 0.10 µg/L in the finished water, but dropped to 0.03 µg/L in the distribution system. Mucochloric acid (*ring* form) was 0.53 µg/L in the GAC influent and 0.05 µg/L in the GAC effluent. Likewise, the *open* form of mucochloric acid was 0.11 and 0.014 µg/L in the GAC influent and effluent, respectively. Similar to that of many other DBPs in this study, MCA (*ring* and *open* forms) was removed on the biologically-active GAC filters. MCA (*ring* form) was partially re-formed at 0.13 µg/L in the finished water, and its concentration remained steady at 0.12 µg/L in the distribution system. The *open* form of mucochloric acid was re-formed in the finished water (0.03 µg/L) and continued to increase in the distribution system (0.16 µg/L). The concentrations of MCA *ring* and *open* forms were qualitative, due to sample matrix co-elutants on the GC column. Due to the relatively high level of bromide in the source water (0.2 mg/L), brominated MX analogs (BMXs) would be expected; however, they were not analyzed for in these samples.

Plant 4, which used chlorine disinfection (applied both to the raw and filtered waters), showed much lower levels of MX (0.015 µg/L) in the finished water, but higher levels (0.02 µg/L) in the chlorinated distribution system. Only a small amount of EMX was detected in finished water from plant 4 (0.011 µg/L), which decreased to below detection in the distribution system. Mucochloric acid levels (both *ring* and *open* forms) were higher in the finished water from plant 4 (0.71 and 0.19 µg/L) than in plant 3 (0.13 and 0.03 µg/L), which contributed to total levels of MX analogs being higher in plant 4 (Figure 29). At plant 4, spent GAC filters were not effective in removing the MX analogues initially formed. This is similar to what was observed for many other DBPs in this study.

Other Halogenated DBPs. A few additional halogenated DBPs were also detected. UNC methods detected dichloroacetamide at 1.2 µg/L in finished water from plant 3 in February 2001 (Table 18). Dichloroacetamide was also observed in the distribution system (2.1 µg/L, plant 3) in October 2001 (Table 19). In addition, broadscreen GC/MS analyses revealed the presence of trichlorophenol and trichlorobenzene-1,2-diol (Table 21) in plant 3 water pre-treated with chlorine (January 2002). These halo-phenols were not observed in the corresponding raw, untreated water, and were not detected in the plant effluent.

Non-Halogenated DBPs. Targeted non-halogenated DBPs observed included trans-2-hexenal (plant 4, February 2001) (Table 18) and dimethylglyoxal (plant 4, October 2001) (Table 19). Levels were 0.7 and 1.4 µg/L, respectively. Several carboxylic acids were also identified as DBPs using broadscreen GC/MS analysis (Table 21). Many carboxylic acids are also seen in the raw, untreated water. However, many were also judged to be formed as DBPs, as their levels increased substantially (2-3X) in the treated waters versus the raw, untreated waters.

Table 18. Additional target DBP results (µg/L) at plants 3 and 4 (2/5/01)

2/5/01	Plant 3 ^a Cl ₂ /NH ₂ Cl						Plant 4 Cl ₂				
Compound	Raw	FI	FE	PE	DS	SDS	FI	FE	PE	DS	SDS
Monochloroacetaldehyde	0	0.4	0.3	0.4	0.3	0.3	1.9	2.2	0.5	0.5	0.4
Dichloroacetaldehyde	0	4.7	2.9	4.3	3.8	3.7	3.9	3.8	3.5	3.6	3.6
Bromochloroacetaldehyde	0	0.5	0.5	0.7	0.3	0.5	0.9	0.6	0.8	0.6	0.5
3,3-Dichloropropenoic acid	0	0.7	0.5	1.5	0.4	1.6	1.0	0.6	0.9	0.9	1.2
Bromochloromethylacetate	0	0	0	0	0	0	0	0	0	0	0
Dichloroacetamide	0	0	0	1.2	1.0	1.9	0	0	0.5	0.4	0.6
TOX (µg/L as Cl ⁻)	0.6	105.1	47.4	87.3	88.0	110.1	127.6	31.8	188.3	154.9	138.5
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
<i>trans</i> -2-Hexenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	0.7	0.6

^aTreatment plant sampled at (1) raw water, (2) GAC filter influent (FI), (3) GAC filter effluent (FE), (4) finished water at plant effluent (PE), (5) distribution system (DS) at average detention time, and (6) simulated distribution system (SDS) at maximum detection time.

Table 19. Additional target DBP results (µg/L) at plants 3 and 4 (10/16/01)

10/16/01	Plant 3 ^a Cl ₂ /NH ₂ Cl						Plant 4 Cl ₂				
Compound	Raw	FI	FE	PE	DS	SDS	FI	FE	PE	DS	SDS
Monochloroacetaldehyde	0	1.2	0	0	0.5	0.6	1.9	0.4	0.4	0.5	0.6
Dichloroacetaldehyde	0	5.1	0.5	0.5	1.2	1.6	5.4	4.2	4.4	4.8	6.1
Bromochloroacetaldehyde	0	3.1	0	0	0.9	1.5	1.1	1.5	1.8	2.0	2.8
3,3-Dichloropropenoic acid	0	0	0	0	0	0	0	0	0	0	0
Bromochloromethylacetate	0	0	0	0	0	0	0	0	0	0	0
Dichloroacetamide	0	1.8	0.2	0	2.1	4.8	0	0	0	0	0
TOX (µg/L as Cl ⁻)	29.1	216.0	82.3	161.0	162.0	141.0	291.0	278.0	278.0	257.0	323.0
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.4	1.6	2.4
<i>trans</i> -2-Hexenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

^aTreatment plant sampled at (1) raw water, (2) GAC filter influent (FI), (3) GAC filter effluent (FE), (4) finished water at plant effluent (PE), (5) distribution system (DS) at average detention time, and (6) simulated distribution system (SDS) at maximum detection time.

Table 20. Halogenated furanone results (µg/L) at plants 3 and 4 (10/16/01)

10/16/01	Plant 3 ^a Cl ₂ /NH ₂ Cl					Plant 4 Cl ₂			
Compound	Raw	FI	FE	PE	DS	FI	FE	PE	DS
MX	<0.02	0.03	<0.02	0.18	<0.02 (0.013)	0.05	<0.02	<0.02 (0.015)	0.02
EMX	<0.02	<0.02	0.05	0.10	0.03	<0.02	0.02	<0.02 (0.011)	<0.02
Mucochloric acid (ring)	<0.02	0.53	0.05	0.13	0.12	0.86	1.00	0.71	0.47
Mucochloric acid (open)	<0.02	0.11	<0.02 (0.014)	0.03	0.16	0.25	0.13	0.19	0.14

^aTreatment plant sampled at (1) raw water, (2) GAC filter influent (FI), (3) GAC filter effluent (FE), (4) finished water at plant effluent (PE), and (5) distribution system (DS) at average detention time. Value in parenthesis is less than the MRL.

Figure 29. Halogenated furanones.

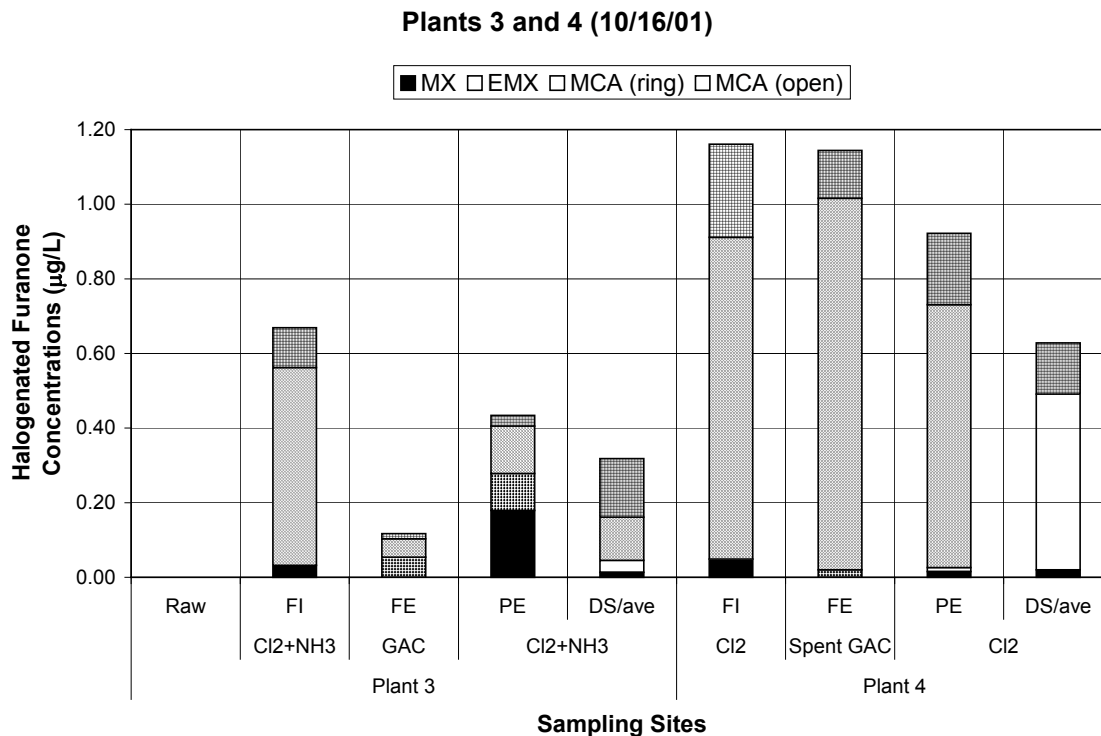


Table 21. Occurrence of other DBPs^a at plants 3 and 4

	11/13/00	8/1/01		1/28/02	
Compound	Plant 3 Cl ₂ /NH ₂ Cl	Plant 3 Cl ₂ /NH ₂ Cl	Plant 4 Cl ₂	Plant 3 Pre- Cl ₂	Plant 3 Cl ₂ /NH ₂ Cl
<u>Halomethanes</u>					
<i>Bromodichloromethane</i>	x	-	x	x	x
<i>Dibromochloromethane</i>	x	x	x	x	x
<i>Bromoform</i>	x	x	x	x	x
<i>Dichloriodomethane</i>	x	x	x	-	-
<i>Bromochloriodomethane</i>	x	-	-	x	-
<u>Haloacids</u>					
<i>Dichloroacetic acid</i>	x	x	x	-	-
<i>Bromochloroacetic acid</i>	x	-	x	-	-
<i>Dibromoacetic acid</i>	x	x	-	-	-
<i>Trichloroacetic acid</i>	x	x	x	x	x
<i>3,3-Dichloropropenoic acid</i>	-	x	x	-	-
<i>Trichloropropenoic acid</i>	-	x	x	-	x
<u>Haloacetoneitriles</u>					
<i>Dichloroacetoneitrile</i>	x	x	x	x	-
<i>Bromochloroacetoneitrile</i>	x	x	x	x	x
<i>Dibromoacetoneitrile</i>	x	x	x	x	-
<i>Tribromoacetoneitrile</i>	x	-	-	-	-
<u>Haloaldehydes</u>					
<i>Dichloroacetaldehyde</i>	x	x	x	x	x
<i>Trichloroacetaldehyde</i>	-	x	x	-	-
<i>2-Bromo-2-methylpropanal</i>	x	x	x	x	x
<i>Iodobutanal^c</i>	x	-	-	-	-
<i>Dichloropropenal^c</i>	-	x	x	-	-
<i>4-Chloro-2-butenal</i>	-	-	-	x	x
<u>Haloketones</u>					
<i>1,1-Dichloropropanone</i>	x	-	x	x	x
<i>1,1,1-Trichloropropanone</i>	x	x	x	x	x
<i>1-Bromo-1,1-dichloropropanone</i>	x	-	x	-	-
<i>1,1,3,3-Tetrachloropropanone</i>	x	x	x	x	x
<i>Pentachloropropanone</i>	x	x	x	x	x
<i>Hexachloropropanone</i>	x	-	x	x	-
<u>Halonitromethanes</u>					
<i>Dichloronitromethane</i>	-	x	x	-	-
<u>Miscellaneous Halogenated DBPs</u>					
<i>Trichlorophenol</i>	-	-	-	x	-
<i>Trichlorobenzene-1,2-diol</i>	-	-	-	x	-

Table 21 (continued)

	11/13/00	8/1/01		1/28/02	
Compound	Plant 3 Cl ₂ /NH ₂ Cl	Plant 3 Cl ₂ /NH ₂ Cl	Plant 4 Cl ₂	Plant 3 Pre- Cl ₂	Plant 3 Cl ₂ /NH ₂ Cl
<u>Non-halogenated DBPs</u>					
3-Methylbutanoic acid	-	-	x	-	-
Pentanoic acid	x	-	-	-	-
<i>Hexanoic acid</i>	x	-	-	-	-
<i>Heptanoic acid</i>	x	-	-	-	-
<i>Octanoic acid</i>	x	-	-	-	x
<i>Nonanoic acid</i>	-	-	-	-	x
<i>Decanoic acid</i>	-	-	-	-	x
<i>Dodecanoic acid</i>	-	-	x	-	x
<i>Tetradecanoic acid</i>	-	-	-	-	x
<i>Pentadecanoic acid</i>	-	-	-	-	x
<i>Hexadecanoic acid</i>	x	-	-	-	x
<i>Octadecanoic acid</i>	-	x	-	-	-
<i>Butanedioic acid</i>	-	-	-	-	x
<i>Pentanedioic acid</i>	-	-	-	-	x
<i>Hexanedioic acid</i>	-	-	-	-	x
<i>Octanedioic acid</i>	-	-	-	-	x
<i>Decanedioic acid</i>	-	-	-	-	x
<i>Undecanedioic acid</i>	-	-	-	-	x

^aDBPs detected by broadscreen gas chromatography/mass spectrometry (GC/MS) technique.

^bCompounds listed in italics were confirmed through the analysis of authentic standards; haloacids and non-halogenated carboxylic acids identified as their methyl esters.

^cExact isomer not known.

SDS Testing. Because plant 3 used chloramines, most DBPs were found to be relatively stable in concentration in the distribution system and in SDS testing. Because plant 4 used free chlorine, THMs and some of the other DBPs were found to increase in concentration in the distribution system and in SDS testing. Figure 30 shows that there was an increase in THM formation—especially for the bromochloro species—during the maximum detention time (140-hr) SDS test of the plant 3 effluent in October 2001 when the bromide level was the highest. However, the formation of the THMs increased by a much higher amount during SDS testing of the plant 4 effluent.

Figure 31 shows the formation and stability of the HANs in SDS testing in October 2001. Although DCAN can undergo base-catalyzed hydrolysis (Stevens et al., 1989), DCAN was stable (and continued to form) in SDS testing at plants 3 and 4, as the pH was 7.0-7.4. The other HANs, including chloroacetonitrile (an EPA study DBP), were stable during this SDS testing.

Figure 32 shows the formation and stability of the haloketones in SDS testing in October 2001. Stevens and colleagues (1989) found 1,1,1-trichloropropanone to be more sensitive to pH than DCAN. In the SDS testing, it did degrade over time. In addition, its brominated analogue 1-bromo-1,1-dichloropropanone, as well as 1,1,3,3-tetrachloropropanone, were detected in the plant effluent samples but not in the SDS testing. Alternatively, chloropropanone was stable during this SDS testing.

Figure 30

Formation of Trihalomethanes in Simulated Distribution System (SDS) Testing (10/16/01): Chloramine and Chlorine Residuals in Plants 3 and 4 SDS Tests, Respectively; Average and Maximum Detention Times of 77 and 140 hr, Respectively

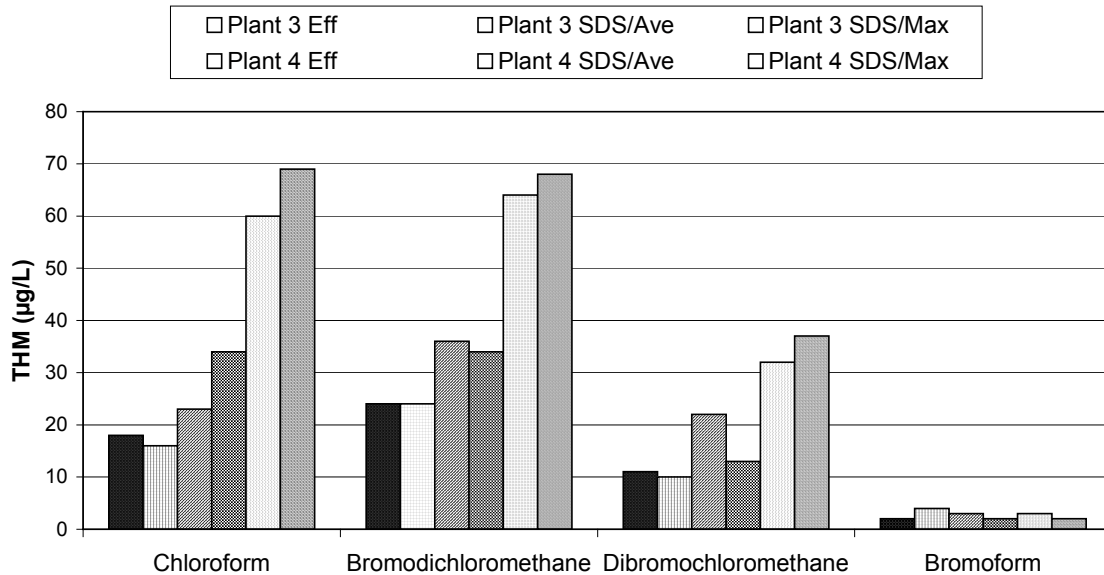
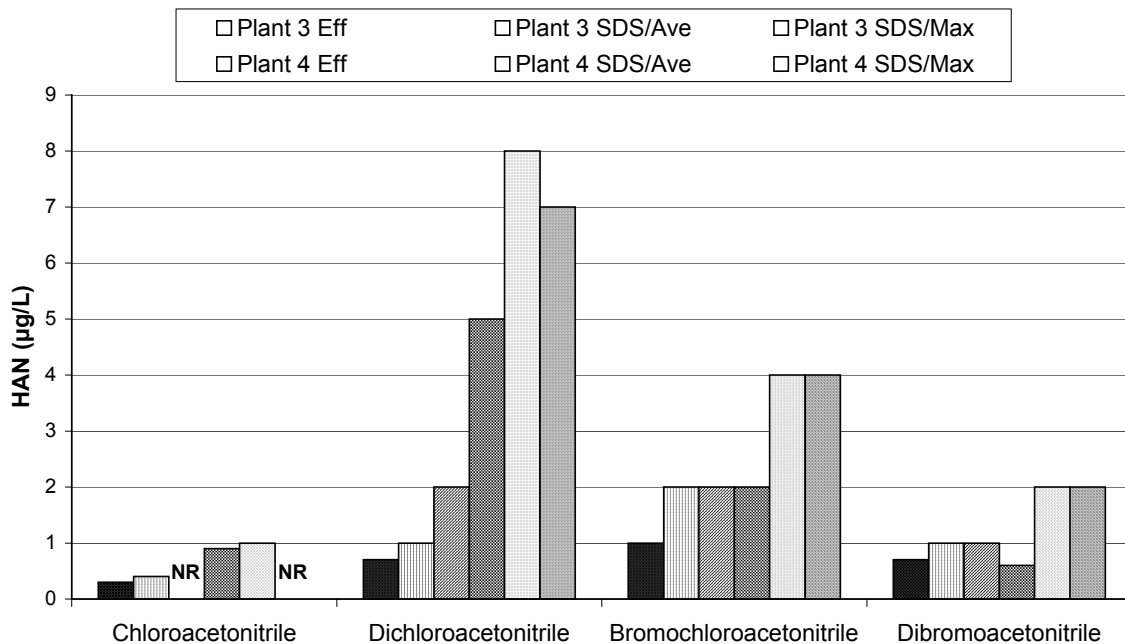


Figure 31

Formation and Stability of Haloacetonitriles in SDS Testing (10/16/01)



NR = Not reported

Figure 33 shows the formation and stability of the haloacetaldehydes in SDS testing in October 2001. Chloral hydrate can also undergo base catalyzed hydrolysis (Stevens et al., 1989). In the SDS testing of the chlorinated water from plant 4, it initially increased in formation and then was somewhat degraded at maximum detention time. Many non-THM DBPs are known to simultaneously form and degrade in a chlorinated distribution system. Alternatively, dichloro- and bromochloroacetaldehyde were stable during this SDS testing.

Figure 32

Formation and Stability of Haloketones in SDS Testing (10/16/01)

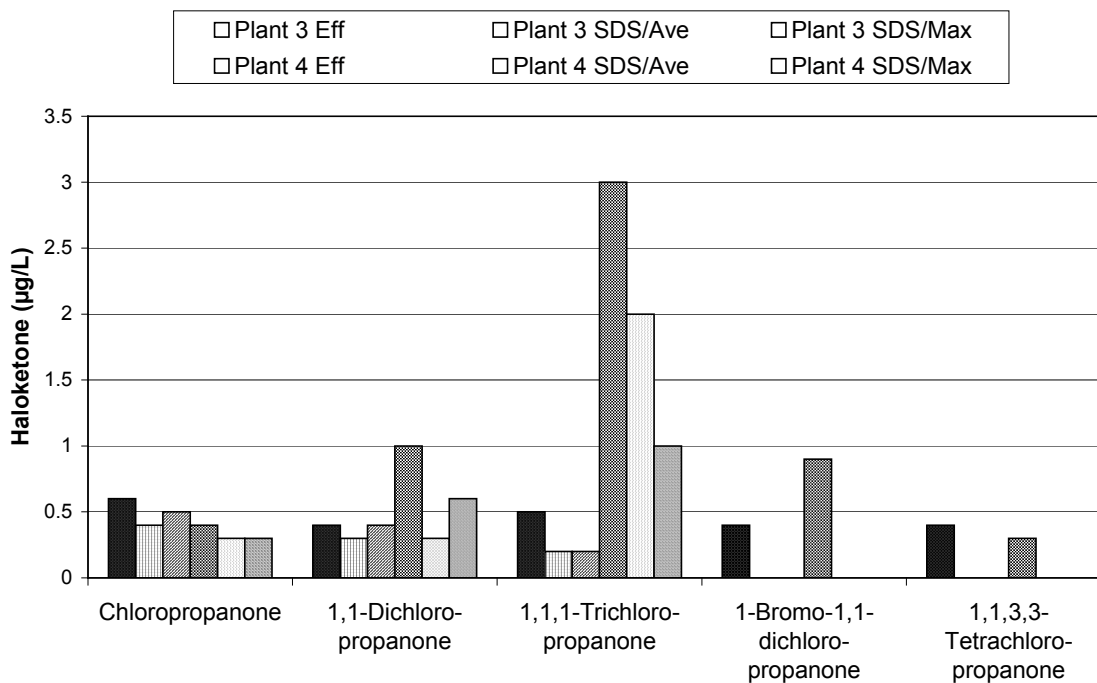
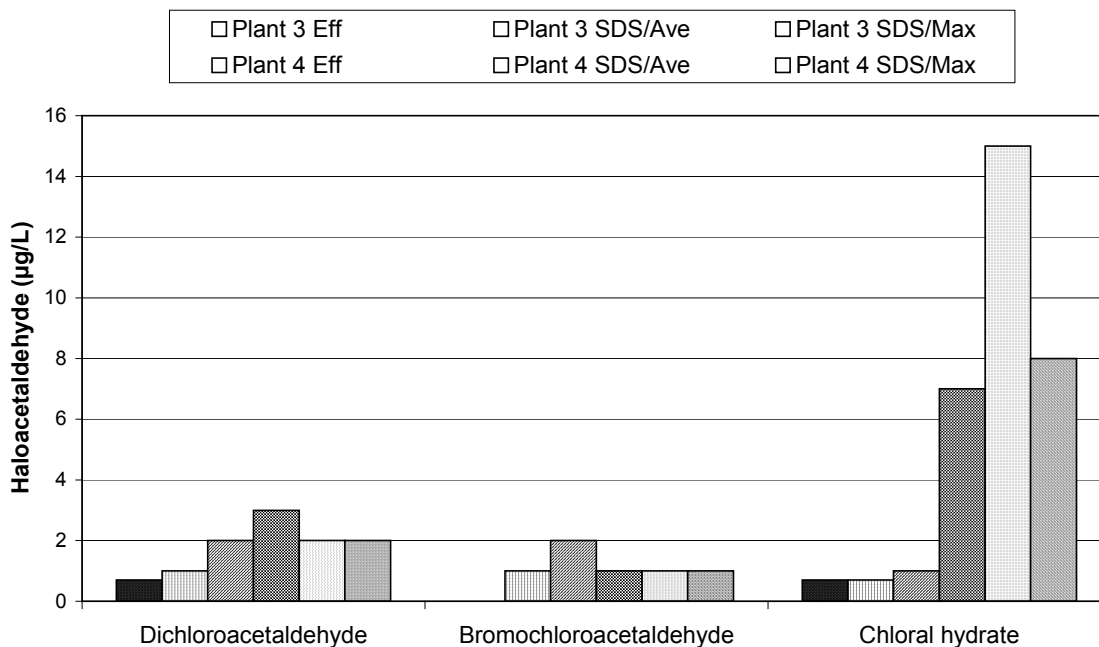


Figure 33

**Formation and Stability of Haloacetaldehydes
in SDS Testing (10/16/01)**



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